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Farm Water Quality Planning
A Water Quality and Technical Assistance Program for California Agriculture

This Reference Sheet is part of the **Farm Water Quality Planning (FWQP)** series, developed for a short course that provides training for growers of irrigated crops who are interested in implementing water quality protection practices. The short course teaches the basic concepts of watersheds, nonpoint source pollution (NPS), self-assessment techniques, and evaluation techniques. Management goals and practices are presented for a variety of cropping systems.

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Reference:

Pesticide Selection to Reduce Impacts on Water Quality

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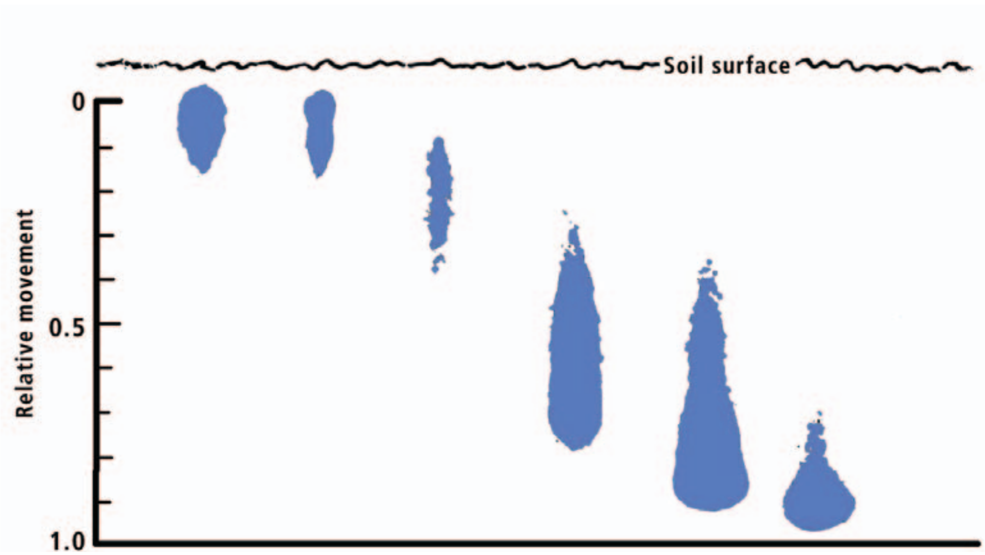
This publication's purpose is to help individual growers make their pesticide-use decisions with water quality in mind. There are several factors that influence a pesticide's potential to affect water quality, including soil properties (e.g., soil texture, organic matter content), pesticide properties (e.g., sorption to soil, half-life), climatic conditions (e.g., rainfall, temperature), and management practices or techniques (e.g., application method, irrigation). Table 1 summarizes how a number of these factors can affect water quality. Along with other site-specific factors, you should take the factors listed in Table 1 into consideration every time you choose a pesticide for application.

Despite all of these factors that can affect a pesticide's potential to impact water quality, though, it is the chemical properties of the pesticide that determine whether it is likely to impact surface water or ground water. In Tables 2, 3, and 4 we have ranked the potential of some common pesticides to impact surface water bodies and ground water according to three pesticide properties: K_{OC}, water solubility, and soil half-life.

K_{OC} is the soil/organic carbon partitioning coefficient. It is highly dependent both on the pesticide's fat solubility and on the organic carbon content of a soil. The larger the K_{OC}, the more strongly the pesticide will sorb to the soil and the less likely it is to migrate to ground water. Water solubility is reported in ppm (parts per million), which is equivalent to milligrams of chemical (in this case, pesticide) that can be dissolved in a liter of water (1 ppm ≈ 1 mg/L). The more soluble a pesticide is, the more likely it is to migrate to ground water or move offsite in surface runoff, although there are exceptions (e.g., glyphosate). A pesticide's soil half-life is the number of days it takes for half of the pesticide to degrade in the soil. The longer the half-life, the more persistent a pesticide is and thus the more probable it is that it will move into ground water or surface water.

Figure 1 gives examples of how K_{OC} and solubility affect the movement of pesticides in soils. Note that K_{OC} and solubility have a strong influence on pesticide leachability. The pesticides in Tables 2, 3, and 4 are reported as having a small, medium, or large potential to impact the surface or ground water. Precautionary actions should be taken above and beyond basic best management practices for pesticides that rank as medium or large potential.

It is important to note that, while the impact of pesticides on groundwater quality is mainly a human health concern (because of its effect on the potability of well water), the effect on surface water quality is often a concern for aquatic organisms or wildlife. This is especially important for pesticides that can run off from fields into streams and lakes, where the pesticides may harm aquatic invertebrates and fish or cause long-term harm to wildlife that feeds on those fish and invertebrates. Tables 2, 3, and 4, list the toxicity of some common pesticides to fish, birds, and other wildlife. By taking appropriate measures (e.g., modifying application methods, application



	CIPC	Diuron	Monuron	Fenac	Amiben	Dicamba
K_{OC}	?	480	150	20	15	2
Solubility (ppm)	?	42	230	5 x10^5	9 x10^5	4 x 10^5

Figure 1. Comparative leaching of several herbicides in soils. USDA photo by C.S. Helling; previously published in Brady 1984.

rates, timing, sediment/erosion control structures, tailwater recovery systems, vegetative buffers, etc.), you can reduce the potential impact to these species.

An additional concern is the potential effect of pesticides on the natural enemies of the target pests. If pesticide applications significantly reduce natural enemy populations, you may have to make more-frequent applications to suppress the resurgent pest populations. More applications, in turn, increase the potential to affect water quality. One of your goals is to protect water quality, so you should select a pesticide that has minimal effect on natural enemies, among other desirable characteristics. You can find more information on some common pesticides' toxicity toward certain natural enemies in the Natural Enemies Handbook (Flint and Dreistadt 1998) (UC ANR Publication 3386).

In summary, your choice of pesticides should be based on several factors. For example, when you are applying pesticides to a location where leaching is a major concern, you should choose a pesticide with a short half-life, high K_{OC}, low solubility, and low toxicity toward aquatic organisms, wildlife, beneficial insects, and other nontarget species. In contrast, when you are applying pesticides to a location where runoff is a major concern, pesticide properties (half-life, K_{OC}, solubility) become less important and management and pesticide toxicity become more important. You should still choose a pesticide with a small half-life, high K_{OC}, low solubility, and low toxicity to aquatic organisms, wildlife, beneficial insects, and other nontarget species, but you also need to pay close attention to field management practices. Erosion should be controlled, for instance, to keep pesticides that are associated with field sediment from making their way into streams and waterways. Pesticides should be incorporated during application if possible and any sediment generated from the field during rainfall or irrigation events should be retained, for instance, in a sediment pond or vegetated filter strip.

In selecting pesticides that are appropriate for a specific crop and pest issue, refer to the University of California IPM Pest Management Guidelines (http://www.ipm.ucdavis.edu), UC Cooperative Extension IPM Advisors, or a certified Pest Control Advisor (PCA). You can use Tables 1 through 4 along with other site-specific information to make an educated decision about which pesticide would be most appropriate in terms of water quality and fish or wildlife toxicity. If the pesticide you are interested in is not in Tables 2 through 4, consult the USDA–NRCS Windows Pesticide Screening Tool (http://www.wcc.nrcs.usda.gov/pestmgt/winpst.html) or the University of California's Pesticide Wise Web site (http://www.pw.ucr.edu), which contains a more comprehensive listing of pesticides and their properties.

Table 1. Water quality impact potential as influenced by water, pesticides, and soil properties (H = High and L = Low).

	Pesticide Properties					**Soil Properties**								**Rainfall/ Irrigation Events**		**Management Practices**	
	High water solubility	Low water solubility	Large K_{OC} (strongly sorbed to soil)	Small K_{OC} (weakly sorbed to soil)	Persistent	Coarse-textured soil	Fine-textured soil	High in organic matter	Low in organic matter	Many large connected soil pores	Few small disconti-nuous soil pores	Shallow water table	Deep water table	Small vol-umes not extending below root zone	Large volumes exceed-ing evapo-trans-piration	Broad-casting	Incor-porating
Risk of ground-water impact	H	L	L	H	H	H	L	L	H	H	L	H	L	L	H*	L†	—‡
Risk of surface-water impact	L#	H	H	L#	H	L	H	H	L	L	H	—#	—#	L#	H	H	L

* can be L if pesticide solubility is low or K_{OC} is large and organic matter is high

† can be H if pesticide has high solubility, low K_{OC} and excessive rainfall/irrigation exists

‡ dependent on pesticide properties, soil properties, and rainfall/irrigation events

\# can be H if excessive runoff exists

Table 2. Water quality impact potential and toxicity information of some common herbicides.

Herbicide Common Name	Herbicide Trade Name	Soil Sorption Index (K_{OC})	Water Solubility (ppm)	Soil Half-Life (days)	Leaching Potential*	Solution Runoff Potential†	Adsorbed Runoff Potential‡	Toxicity to Fish#	Toxicity to Birds and Other Wildlife§	References
					Phenoxy and Benzoic Acids					
2,4-D dimethylamine	2,4-D amine	20	890	10	Medium	Medium	Small	Moderate to slight	High to Slight	1, 2
DCPA	Dacthal	5,000	0.5	100	Small	Medium	Large	Slight to practically nontoxic	Moderate to practically nontoxic	1, 2
Dicamba	Banvel	2	$4x10^5$	14	Large	Medium	Small	Practically nontoxic	Practically nontoxic	1, 2
					Triazines					
Atrazine	Aatrex	100	33	60	Large	Large	Medium	Slight	Practically nontoxic	1, 2
Cyanazine	Bladex	190	170	14	Medium	Medium	Small	Slight to moderate	Slight to moderate	1, 2
Hexazinone	Velpar	54	33,000	90	Large	Large	Medium	Slight	Slight to practically nontoxic	1, 2
Metribuzin	Sencor	60	1,220	40	Large	Large	Small	Slight	Moderate to slight	1, 2
Prometon	Pramitol	150	720	500	Large	Large	Medium	Practically nontoxic	Slight	1, 3
Prometryn	Promet	400	33	60	Medium	Large	Medium	Moderate	Practically nontoxic	1, 2
Simazine	Simazine	130	6.2	60	Large	Large	Medium	Slight to practically nontoxic	Practically nontoxic	1, 2
					Substituted Ureas					
Chlorsulfuron	Glean	40	7,000	160	Large	Large	Medium	Practically nontoxic	Practically nontoxic	1, 4
Diuron	Karmex	480	42	90	Medium	Large	Medium	Moderate	Slight	1, 3
Linuron	Lorox	400	75	60	Medium	Large	Medium	Slight	Slight	1, 2
Sulfometuron-methyl	Oust	78	70	20	Medium	Large	Small	Slight	Practically nontoxic	1, 2
Tebuthiuron	Spike	80	2,500	360	Large	Large	Medium	Slight to practically nontoxic	Practically nontoxic	1, 2
					Thiocarbamates					
Butylate	Sutan	400	44	13	Small	Large	Small	Moderate	Practically nontoxic	1, 2
Cycloate	Ro-Neet	430	95	30	Medium	Large	Small	Moderate	Practically nontoxic	1, 4

* The potential for the pesticide to be lost via leaching.

† The potential for the pesticide to be lost by being transported away in surface runoff in the solution phase.

‡ The potential for the pesticide to be lost by being transported away in surface runoff while adsorbed to soil particles.

The toxicity categories are defined in Table 5. Most toxicities are reported for fish, although some include aquatic invertebrates also.

§ The toxicity categories are defined in Table 5. Most toxicities are reported for birds, although some include rabbits and other wildlife also.

Table 2. Water quality impact potential and toxicity information of some common herbicides (con't).

Herbicide Common Name	Herbicide Trade Name	Soil Sorption Index (K_{OC})	Water Solubility (ppm)	Soil Half-Life (days)	Leaching Potential*	Solution Runoff Potential†	Adsorbed Runoff Potential‡	Toxicity to Fish#	Toxicity to Birds and Other Wildlife§	References
EPTC	Eradicane	200	344	6	Small	Medium	Small	Slight	Slight to practically nontoxic	1, 2
Molinate	Molinate	190	970	21	Medium	Medium	Small	High to slight	Practically nontoxic	1, 2
Pebulate	Tillam	430	100	14	Small	Medium	Small	Moderate	Practically nontoxic	1, 4
Triallate	Far-Go	2,400	4	82	Small	Large	Large	High	Practically nontoxic	1, 2
					Bipyridyliums					
Diquat dibromide	Diquat	$1x10^6$	$7.2x10^5$	1,000	Very small	Small	Large	Moderate to practically nontoxic	Slight to moderate	1, 2
Paraquat	Gramoxone	$1x10^6$	$6.2x10^5$	1,000	Very small	Small	Large	Moderate to slight	Moderate	1, 2
					Chloroacetamides					
Alachlor	Lasso	170	240	15	Medium	Medium	Small	Moderate	Practically nontoxic	1, 2
Metolachlor	Dual	200	530	90	High	High	Medium	Moderate	Slight to practically nontoxic	1, 2
					Dinitroanilines					
Oryzalin	Surflan	600	2.5	20	Small	Medium	Small	High	Slight to practically nontoxic	1, 2
Pendimethalin	Prowl	5,000	0.28	90	Small	Medium	Large	High	Slight	1, 2
Trifluralin	Treflan	8,000	0.3	60	Small	Medium	Large	Very high	Practically nontoxic	1, 2
					Nitriles					
Bromoxynil	Buctril	192	0.8	8	Small	Small	Medium	Very high to moderate	High to moderate	1, 2
Dichlobenil	Casoron	400	21.2	60	Medium	Large	Medium	Moderate to slight	Slight to practically nontoxic	1, 4

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† The potential for the pesticide to be lost by being transported away in surface runoff in the solution phase.
‡ The potential for the pesticide to be lost by being transported away in surface runoff while adsorbed to soil particles.
# The toxicity categories are defined in Table 5. Most toxicities are reported for fish, although some include aquatic invertebrates also.
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Table 2. Water quality impact potential and toxicity information of some common herbicides (con't).

Herbicide Common Name	Herbicide Trade Name	Soil Sorption Index (K_{OC})	Water Solubility (ppm)	Soil Half-Life (days)	Leaching Potential*	Solution Runoff Potential†	Adsorbed Runoff Potential‡	Toxicity to Fish#	Toxicity to Birds and Other Wildlife§	References
Other Herbicides										
Acrolein	Magnacide-H	1	$2.1x10^5$	14	Large	Medium	Small	High to slight	Very high to high	1, 4
Bensulide	Prefar	1,000	5.6	120	Medium	Large	Large	Moderate to high	Slight	1, 2
Bentazon	Basagran	35	$2.3x10^6$	20	Large	Large	Small	Practically nontoxic	Slight	5, 1, 2
Bromacil	Hyvar	32	700	60	Large	Large	Medium	Slight to practically nontoxic	Practically nontoxic	1, 2
Clopyralid	Stinger	6	1,000	30	Large	Medium	Small	Practically nontoxic	Slight to practically nontoxic	1, 5
Diethayl-ethyl	Antor	1,400	105	21	Small	Medium	Medium	Moderate	N/A	1, 6
Ethofumesate	Norton	340	50	30	Medium	Large	Small	Slight to practically nontoxic	Practically nontoxic	1, 4
Glyphosate	Roundup	24,000	12,000	47	Very small	Large	Large	Practically non-Toxic	Slight	1, 2
Imazethapyr	Pursuit	10	$2x10^5$	90	Large	Large	Medium	Practically nontoxic	Practically nontoxic	1, 4
Isoxaben	Snapshot TG	1,400	1	100	Small	Large	Large	High to moderate	Practically nontoxic	1, 4
Napropamide	Devrinol	400	74	70	Medium	Large	Medium	Moderate to slight	Practically nontoxic	1, 2
Norflurazon	Evital	600	28	90	Medium	Large	Medium	Moderate	Slight to practically nontoxic	1, 4
Oxyfluorfen	Goal	$1x10^5$	0.1	35	Very small	Large	Medium	High	Practically nontoxic	1, 2
Propyzamide	Kerb	200	15	60	Large	Large	Medium	Slight to practically nontoxic	Practically nontoxic	1, 4
Pyrazon	Pyramin	120	400	21	Large	Large	Medium	Slight	Slight	1, 3
Rimsulfuron	Matrix	47	7,300	10	Medium	Medium	Small	Practically nontoxic	Slight to moderate	1, 3

* The potential for the pesticide to be lost via leaching.

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‡ The potential for the pesticide to be lost by being transported away in surface runoff while adsorbed to soil particles.

The toxicity categories are defined in Table 5. Most toxicities are reported for fish, although some include aquatic invertebrates also.

§ The toxicity categories are defined in Table 5. Most toxicities are reported for birds, although some include rabbits and other wildlife also.

Table 3. Water quality impact potential of common insecticides, nematicides, and other pesticides.

Pesticide Common Name	Pesticide Trade Name	Soil Sorption Index (K_{OC})	Water Solubility (ppm)	Soil Half-Life (days)	Leaching Potential	Solution Runoff Potential	Adsorbed Runoff Potential	Toxicity to Fish	Toxicity to Birds and Other Wildlife	References
					Pyrethroids and Botanicals					
Esfenvalerate	Asana	5,300	0.002	35	Small	Medium	Medium	Very high	Slight	1, 2
Fenvalerate	Pydrin	5,300	0.002	35	Small	Medium	Medium	High to moderate	Practically nontoxic	1, 4
Fluvalinate	Mavrik	$1x10^6$	0.005	30	Very small	Small	Medium	Very high	Slight	1, 2
Permethrin	Ambush	$1x10^5$	0.006	30	Very small	Small	Medium	Very high	Practically nontoxic	1, 2
Resmethrin	Crossfire	$1x10^5$	0.01	30	Very small	Small	Medium	Very high	Practically nontoxic	1, 2
					Carbamates					
Aldicarb	Temik	30	6,000	30	Large	Medium	Small	Moderate	Very high	1, 2
Carbaryl	Sevin	300	120	10	Small	Medium	Small	Moderate	Practically nontoxic	1, 2
Carbofuran	Furadan	22	351	50	Large	Large	Medium	High	High	1, 2
Formetanate	Carzol	$1x10^6$	$5x10^5$	100	Very small	Small	Large	Moderate to slight	High	1, 4
Methiocarb	Mesurol	300	24	30	Medium	Large	Small	Moderate to high	Very high to high	1, 4
Methomyl	Lannate	72	58,000	30	Large	Medium	Small	High to moderate	High	1, 2
Oxamyl	Vydate-L	$2.8x10^5$	25	4	Small	Medium	Small	Moderate to slight	Very high	1, 2
Thiodicarb	Larvin	350	19.1	7	Small	Large	Small	High to moderate	Practically nontoxic	1, 4
					Organophosphates					
Acephate	Orthene	2	818,000	3	Small	Medium	Small	Slight to practically nontoxic	Moderate to slight	1, 4
Azinphos-methyl	Guthion	1,000	29	10	Small	Medium	Medium	Very high to moderate	Slight to moderate	1, 2
Chlorpyrifos	Lorsban	6,070	0.4	30	Small	Small	Medium	Very high	Very high to moderate	1, 2
Chlorpyrifos-methyl	Dursban methyl	3,000	4	7	Small	Medium	Medium	Moderate to practically nontoxic	Slight	1, 4
Diazinon	D.Z.N.	1,000	60	40	Small	High	High	High to slight	Very high to high	1, 2
Dimethoate	Cygon	20	39,800	7	Medium	Medium	Small	Moderate	Very high to moderate	1, 2
Disulfoton	Di-Syston	600	25	30	Medium	Large	Small	High	Moderate	1, 2
Fenamiphos	Nemacur	100	400	50	Large	Large	Medium	High to moderate	Very high	1, 2

Table 3. Water quality impact potential of common insecticides, nematicides and other pesticides (con't).

Pesticide Common Name	Pesticide Trade Name	Soil Sorption Index (K_{OC})	Water Solubility (ppm)	Soil Half-Life (days)	Leaching Potential	Solution Runoff Potential	Adsorbed Runoff Potential	Toxicity to Fish	Toxicity to Birds and Other Wildlife	References
Fonofos	Dyfonate	870	16.9	40	Small	Large	Small	High	Extremely high	1, 2
Malathion	Cythion	1,800	130	1	Small	Small	Small	Very high to slight	Moderate	1, 2
Methyl parathion	Penncap-M	5,100	60	5	Small	Medium	Medium	Very high to high	Extreme	1, 2
Naled	Dibrom	180	2,000	1	Small	Medium	Small	High to moderate	High to moderate	1, 2
Parathion	Phoskil	5,000	24	14	Small	Medium	Medium	Very high to moderate	Very high to high	1, 4
Phorate	Thimet	1,000	22	60	Small	Large	Large	Very high	Very high to high	1, 2
Terbufos	Counter	500	5	5	Small	Medium	Small	High	Very high	1, 2
Trichlorfon	Dylox	10	1.2×10^5	10	Large	Medium	Small	Very high	High to moderate	1, 2
Organochlorides (Chlorinated hydrocarbons)										
Dicofol	Kelthane	1.8×10^5	1	60	Very small	Small	Large	High	Slight	1, 2
Dienochlor	Pentac	1,000	25	300	Medium	Large	Large	Very high to high	Practically nontoxic	1, 2
Endosulfan	Thiodan	12,400	0.32	50	Very small	Medium	Large	Very high	High to moderate	1, 2
Lindane	Isotox	1,100	7	400	Medium	Large	Large	Very high to high	Moderate to practically nontoxic	1, 2
Other										
Abamectin	Avid	5,000	5	28	Small	Medium	Medium	Very high	Practically nontoxic	1, 2
Bacillus thuringensis	Dipel	N/A	N/A	120	Very small (estimated)	N/A	N/A	Practically nontoxic	Practically nontoxic	2
Bifenthrin	Talstar	2.4×10^5	0.1	26	Very small	Small	Medium	Very high	Slight to practically nontoxic	1, 4
Cryolite	Kryocide	10,000	420	3,000	Small	Large	Large	Slight to practically nontoxic	Practically nontoxic	1, 4
Diflubenzuron	Dimilin	10,000	0.08	10	Small	Small	Medium	Practically nontoxic	Practically nontoxic	1, 2
Ethoprop	Mocap	70	750	25	Large	Medium	Small	Very high to slight	Very high to slight	1, 4
Imidacloprid	Admire	440	580	127	Large	Large	Medium	Slight to practically nontoxic	High to slight	1, 4
Metaldehyde	Metaldehyde	240	230	10	Small	Medium	Small	Moderate to practically nontoxic	Moderate to slight	1, 4
Oxydemeton-methyl	Metasystox-R	10	1×10^6	10	Large	Medium	Small	High to slight	High to slight	1, 4

Table 4. Water quality impact potential of common fungicides.

Fungicide Common Name	Fungicide Trade Name	Soil Sorption Index (K_{OC})	Water Solubility (ppm)	Soil Half-Life (days)	Leaching Potential	Solution Runoff Potential	Adsorbed Runoff Potential	Toxicity to Fish	Toxicity to Birds and Other Wildlife	Reference
					Dithiocarbamates					
Mancozeb	Dithane	2,000	6	70	Small	Large	Large	High to moderate	Slight	1, 2
Maneb	Maneb	2,000	6	70	Small	Large	Large	High	Practically nontoxic	1, 2
					Dicarboximides					
Iprodione	Rovral	700	13.9	14	Small	Large	Small	Moderate	Slight	1, 2
Vinclozolin	Ronilan	100	1,000	20	Medium	Medium	Small	Moderate to slight	Practically nontoxic	1, 2
					Organochlorides (Chlorinated hydrocarbons)					
Chlorothalonil	Bravo	1,380	0.6	30	Small	Medium	Medium	High	Practically nontoxic	1, 2
PCNB (Quintozene)	Terraclor	5,000	0.44	21	Small	Small	Medium	High	Practically nontoxic	1, 2
Dichloropropene	Telone II	32	2,250	10	Medium	Medium	Small	Moderate	Moderate to practically nontoxic	1, 4
					Other Fungicides					
Bacillus subtilis	Serenade	N/A	N/A	N/A	Very small (estimated)	Small	Small	Practically nontoxic	Practically nontoxic	3, 7
Benomyl	Benlate	1,900	2	67	Very small	Small	Small	Very high to high	Moderate to practically nontoxic	1, 2
Captan	Captan	200	5.1	3	Small	Medium	Small	Very high	Practically nontoxic	1, 2
Carboxin	Vitavax	260	195	7	Small	Medium	Small	High to slight	Slight to practically nontoxic	1, 4
Chloropicrin	Chlor-O-Pic	62	2,270	1	Small	Medium	Small	Very high to high	N/A	1, 4
Dicloran	Botran	1,000	7	10	Small	Medium	Medium	High to slight	Slight to practically nontoxic	1, 4
Fosetyl-Al technical	Aliette	20	$1.2x10^5$	1	Very small	Medium	Small	Practically nontoxic	Practically nontoxic	1, 4
Metalaxyl	Ridomil	70	8,400	50	Large	Large	Medium	Practically nontoxic	Practically nontoxic	1, 2
Triadimefon	Bayleton	300	71.5	26	Medium	Large	Small	Slight to practically nontoxic	Practically nontoxic	1, 2
Triflumizole	Procure	40	12,500	14	Medium	Medium	Small	High to moderate	Practically nontoxic	1, 4

Table 5. Definition of toxicity categories used in Tables 2, 3, and 4.

Toxicity Rating	Bird Acute Oral LD_{50} (mg/kg)	Fish water LC_{50}(mg/L)
Very high	<10	<0.1
High	10–50	0.1–1
Moderate	>50–500	>1–10
Slight	>500–2000	>10–100
Practically nontoxic	>2000	>100

SOURCE: Modified from Kamrin, 1997, Lewis Publishers (an imprint of CRC Press).

REFERENCES FOR TABLES 2 THROUGH 4

Note: These references are numbered, and they are referenced by number in Tables 2 through 4.

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