INTRODUCTION

Pesticide products are very useful tools in agricultural production. Used correctly, they contribute to higher productivity and higher quality characteristics in crops. By protecting crops from pests, pesticide products also contribute to the economical, safe, and nutritious variety of foods consumers enjoy.

As well as the benefits of pesticide use, there are risks to humans, livestock, wildlife, and the environment. Potential problems can be avoided by understanding these risks and knowing how to manage them.

The intent of this book is to help you learn how to store, handle, and apply pesticides in a safe and cost-effective manner. The next two chapters describe the details of storage and handling structures as well as the management practices to make them work. The final chapter describes the principles of application, how to select and care for application equipment, and the best management practices to keep products on target and out of natural resource areas.

For the purposes of this book, a **pest** is any harmful or troublesome organism that causes an unacceptable level of loss in crop yield or quality. Pests include weeds, insects, diseases, or even animals such as rodents or deer. A **pesticide** is any chemical designed to kill or control a pest. The emphasis in this book will be on insecticides, fungicides, and herbicides.

BIOLOGICAL CONTROL

Parasites are used to control white-fly in greenhouses. This is a biological method of pest control, where a living organism is being used to kill another living organism (i.e., the target pest). Predators of the pests are introduced to the crop.

GENETIC IMPROVEMENTS

More modern methods of control involve genetic engineering of the crop to give it natural resistance to a pest. Other examples are the release of sterile insects, and breeding disease-resistant and herbicide-resistant plant varieties (shown here).

PHYSICAL CONTROL

Physical control removes the pest from or prevents its entry into the crop. Power vacuuming, propane flaming, and plastic-lined trenches (above) have been tested against the Colorado Potato Beetle. Cultivating weeds is another means of physical control.

CHEMICAL CONTROL

The application of pesticides by sprayers is a chemical method of pest control. Pesticides are substances used specifically to control pests like insects, weeds, or diseases.

CULTURAL CONTROL

Crop rotation and the use of disease-resistant varieties of crops are examples of cultural control.

INTRODUCTION

Proper use of pesticides helps create high quality farm produce.

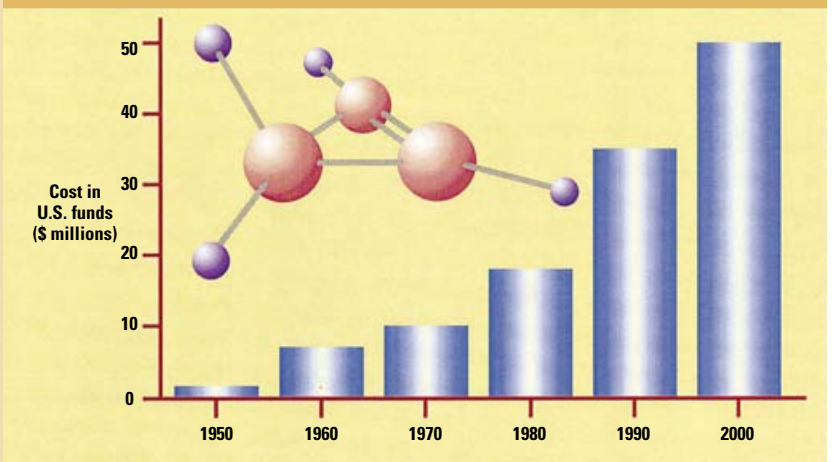
A CENTURY OF DEVELOPMENT

Our ancestors fought pests using their hands, mechanical tools, animal-powered equipment, and finally mechanical power. Early pesticides included salt, sulphur, bluestone, lime, mercury, ashes, copper, lead, and arsenic. Around 1900 we started to use industrially processed chemicals for pest control, and enormous advancements have been made since that time.

Following World War II, new manmade pesticides dramatically changed the practices of pest control forever. The chemical 2,4-Dichlorophenoxy acetic acid (2,4-D) allowed the first large-scale control of weeds in corn and cereals. The organochlorine insecticides revolutionized insect control by providing effective control of many crop- and life-threatening insect pests with relatively low toxicity to humans. Triazine herbicides like simazine, atrazine, and cyanazine allowed farmers to grow much larger areas of corn with all the attendant benefits to food and livestock production. Organophosphate and carbamate insecticides, ethylene-bis-dithiocarbamates (EBDCs), and Captan-like fungicides greatly improved horticultural crop production practices, as well as those for field crops, by the early 1960s.

Of course there were some problems identified with this otherwise positive trend in agriculture. Pesticides affected other organisms that were not the target of the treatment. Spilled pesticides contaminated ponds and streams when care was not taken during storage and handling. Wildlife, primarily fish and birds, were negatively impacted when persistent or bio-accumulating chemicals got into their food chain or primary habitat. Certain classes of pesticides had an acute risk to humans, resulting in cases of mild to severe poisoning.

PESTICIDE DEVELOPMENT COSTS



New pest control products are subjected to rigorous efficacy, environmental, and safety testing. The process takes several years and many millions of dollars.

INTRODUCTION

To overcome many of these problems, farmers along with government, industry and university toxicologists cooperated to develop methods to better evaluate environmental impact and human toxicity before a product was introduced. Each new pesticide is rigorously tested before it reaches the market – taking seven to 10 years and costing up to $100-million. Researchers and regulators now have much more reliable information on toxicity residue levels in food, and the fate and longevity of pesticides in soil and water. This knowledge helps establish whether the benefits of the product outweigh the risk and under what conditions the product may be used to minimize those risks.

An even more promising development in the last decade is the production of narrower spectrum and low-dosage pesticides. Although these are positive trends, with each product we must be aware of any negative characteristics possessed by the specific product or product group. These products are gradually replacing the older ones. Industry now equips farmers with safer, more effective pesticide products than ever before.

The average citizen may not recognize the impact of pests on the food supply. Worldwide, losses due to plant pests are high: field and storage losses are estimated to be as much as 40% – in spite of a multitude of pest control options.

BENEFITS

When used properly, pesticides provide an economical method of managing pests in just about every crop produced in Ontario. They provide the following benefits:

- crop protection from damage and yield losses due to competing organisms
- moderate- to low-cost control method
- improved product quality
  - blemish-free fruit
  - insect-free vegetables
  - higher-yielding grain crops
- harmful pests, some of which produce human disease and dangerous toxins, prevented from reaching our food supply
- improved harvestability when weeds and other pests are controlled
- improved yields on productive land
- more choices in crop production
- part of an integrated approach to controlling pests.

Herbicides can be used to prevent weed infestation – or rescue food crops from failure.

Growers can learn about the safe use of pesticides through pesticide safety workshops.

Consumers expect blemish-free fruit and insect-free vegetables. Pesticides help control damage to high value crops.

INTRODUCTION

Risk = Toxicity x Exposure

Some pesticides that protect crops can be directly harmful to wildlife. Choose chemicals with less toxicity. This carcass of a Mallard duck was found in a cabbage field treated with insecticides.

It's industry's responsibility to test and determine the conditions under which pesticides may be used safely.

RISKS

Certain pesticides, when they are not stored, handled, or applied properly, can lead to:

- human exposure to toxic materials, which may cause injury, death, or long-term health effects (e.g., cancer, asthma)
- contamination of water, air, soil, and habitat
- direct wildlife exposure to toxic materials that may harm natural predators, pollinators, beneficial soil organisms, fish, birds, and other wildlife – particularly with spills, but also with drift and leaching into water bodies
- bio-accumulation of some products in body tissues – this presents a risk to the food chain
- excess residue on food through overuse and/or improper timing of use on food products such as fruits and vegetables – this could lead to seizure of the crop
- pest resistance, which occurs when the same material or products within the same chemical group are used continually
- economic losses due to crop damage or poor pest control
- disruption of natural control agents. Many pesticides are non-selective and upset the predator-parasite balance. The removal of natural pest control increases dependence on chemical pesticides.

It's the responsibility of pesticide users to read and follow label instructions, and handle and use the products wisely. Not doing so poses risks to key beneficials such as pollinators.

INTRODUCTION

FATE OF PESTICIDES IN THE ENVIRONMENT

Pesticides dissipate at varying rates. Simple chemicals often dissipate more quickly than complex chemicals.

The physical and chemical properties of pesticides influence their potential to harm the environment. The most important properties to know are:

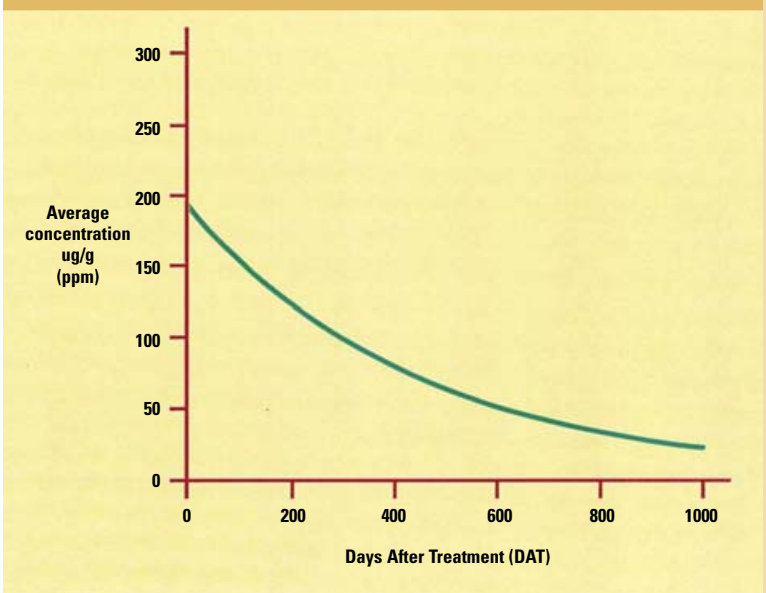
- **degradation** – ability to break down in the environment
  - the longer a pesticide takes to degrade, the greater the risk for water contamination
  - generally, complex chemicals like some organophosphates last longer since they can't be broken down readily by soil microbes
  - soil conditions that provide excellent habitat for microbial growth may also lead to more rapid rates of degradation
- **volatility** – ability to move into the air, e.g., hormone herbicides
- **solubility** in water – ability to leach into groundwater, e.g., metalochlor can leach more readily than atrazine
- **adsorption** – binding characteristics with soil particles, e.g., triazines bond to soil particles
- **absorption** – ability to move into organisms or structures
- **bio-accumulation** – ability to accumulate in body tissues.

These properties, combined with processes such as runoff, leaching, wind and water erosion, and vapour drift, determine what happens to a pesticide and where it ends up after it's released into the environment.

Glyphosate (found in products such as Roundup® and Touchdown®) is a simple chemical and will break down readily or will be rendered inactive by soil adsorption.

Negative impacts on the environment can be greatly reduced if chemicals are stored and handled safely. Further, proper application techniques that ensure pesticides are used at the right pest stage, at the right time, and on target will also reduce environmental impact.

HOW PESTICIDES DEGRADE



When present in soil, pesticides degrade over time. Dissipation is the lowering of pesticide concentrations in a specified area (soil, plant, atmosphere) due to the combination of biological, physical, and chemical activities such as photodecomposition into other chemicals.

INTRODUCTION

PHOTODECOMPOSITION – some of the foliage and soil-applied pesticides can be broken down by sunlight into other chemicals.

EVAPORATION – some of the spray products applied under warm and dry conditions may be vaporized before reaching the target.

VOLATILIZATION – some pest control products (both plant-applied and soil-applied) and their adjuvants are quite volatile and may be lost to the atmosphere before reaching target pests. Some products, such as soil fumigants and pest control products for stored grain, work best if volatile.

RUNOFF – dissolved, suspended and adsorbed pesticide products can run off farmland in the event of a spill or with snowmelt and heavy rains.

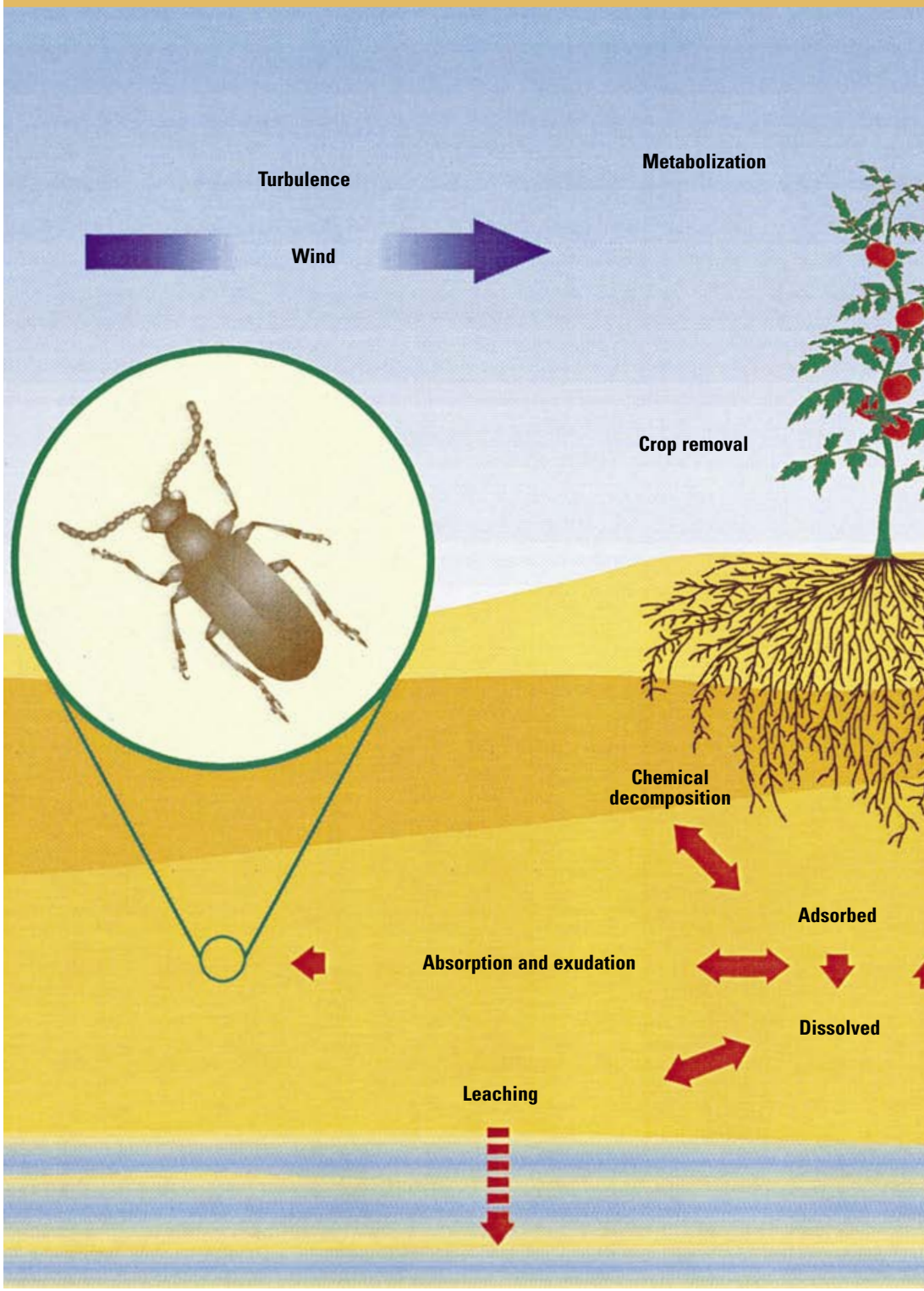
TURBULENCE – air currents and winds can move sprayed products off-target and keep them in suspension.

CROP REMOVAL – some materials will remain on or be absorbed into the harvested crop.

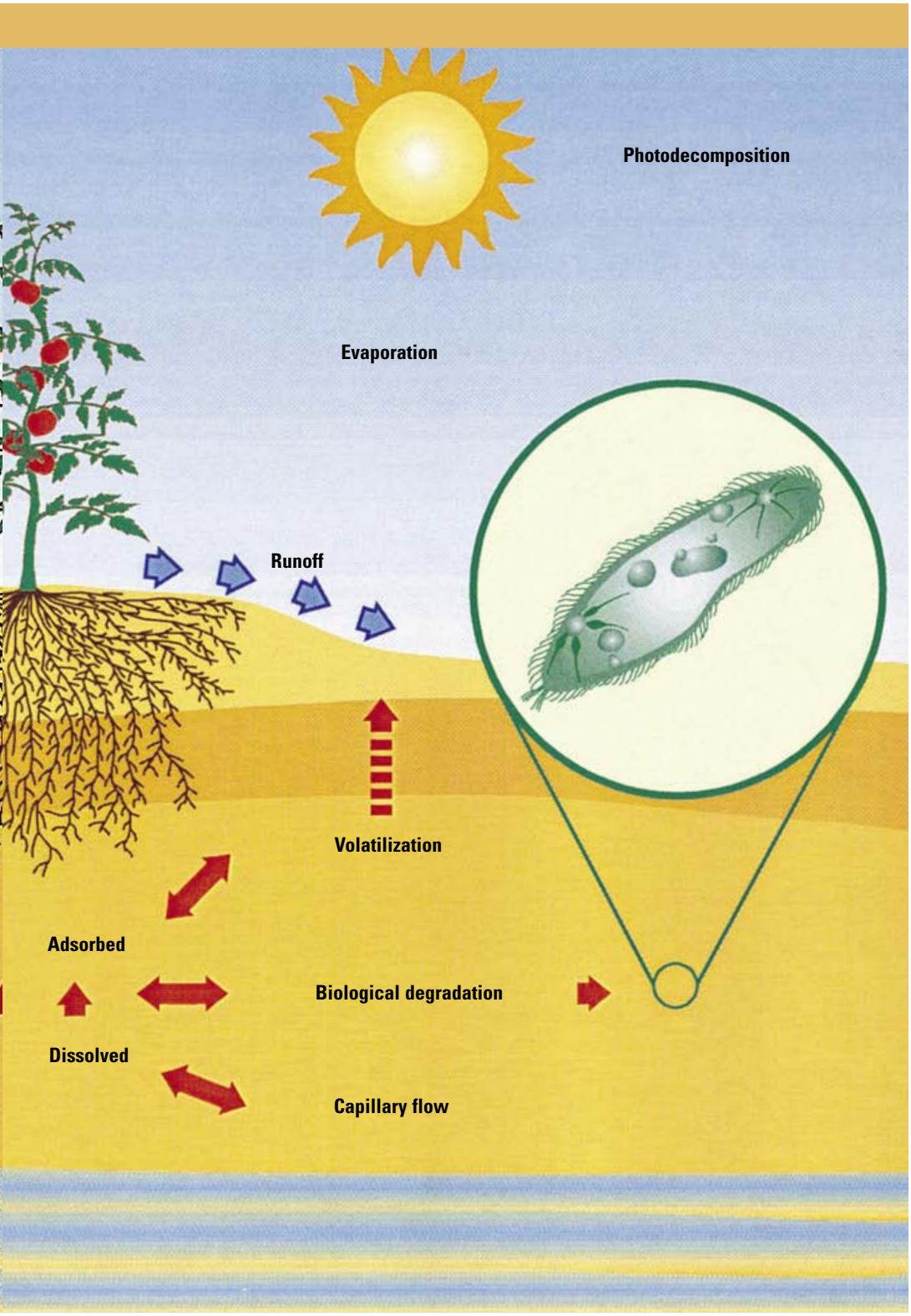
METABOLIZATION BY PLANT – plant will take up some of the chemicals. Here, the chemical will be metabolized, perform its task, and be degraded by the plant.

ABSORPTION AND EXUDATION – target insect pests and non-target animals can absorb pesticide products – orally, through the skin, or through respiration. These chemicals can perform their intended function, bio-accumulate in non-target pests, or be excreted (exudated).

FATE OF PESTICIDES IN THE ENVIRONMENT



INTRODUCTION



ADSORPTION – pesticides and their breakdown products can become attached to negatively charged soil particles, i.e., humus and clay. Attached materials can be volatilized, absorbed, decomposed by chemical or biological means, remain attached, or dissolve in the soil solution.

CHEMICAL DECOMPOSITION – chemicals in the soil, such as lime and naturally occurring acids, can break down pesticide chemicals.

BIOLOGICAL DEGRADATION – soil microbes and other living organisms can use their own enzymes to degrade pesticides and break down products.

DISSOLVED – soluble (salt-like) chemicals can become part of the soil solution. Soil solutions can continue to interact with soil chemical and biological processes or be lost by leaching and runoff.

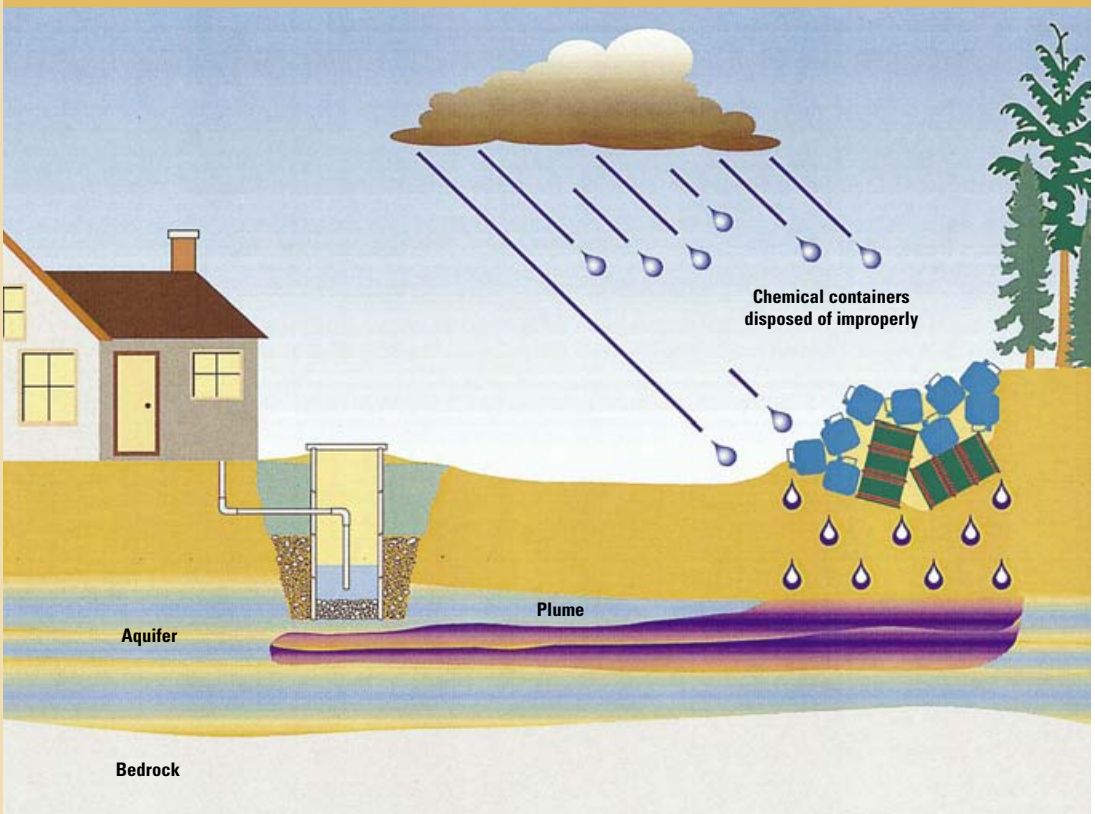
LEACHING – soluble pesticides and their breakdown products can percolate through the soil by gravity and reach the water table. Aquifers can be contaminated by very minute amounts of these products.

CAPILLARY FLOW – products can move with soil solutions and soil water upwards and laterally due to soil pore sizes and continuity of pores. In this way, pesticide products can be "recycled" through the soil medium and be subject to all the above fates.

INTRODUCTION

HOW PESTICIDES CAN CONTAMINATE WATER RESOURCES

POTENTIAL FOR GROUNDWATER CONTAMINATION



Pesticides or pesticide breakdown products from improperly stored containers can contaminate groundwater resources.

For information on safeguarding wells from contamination, see *Water Wells*, a Best Management Practices book.

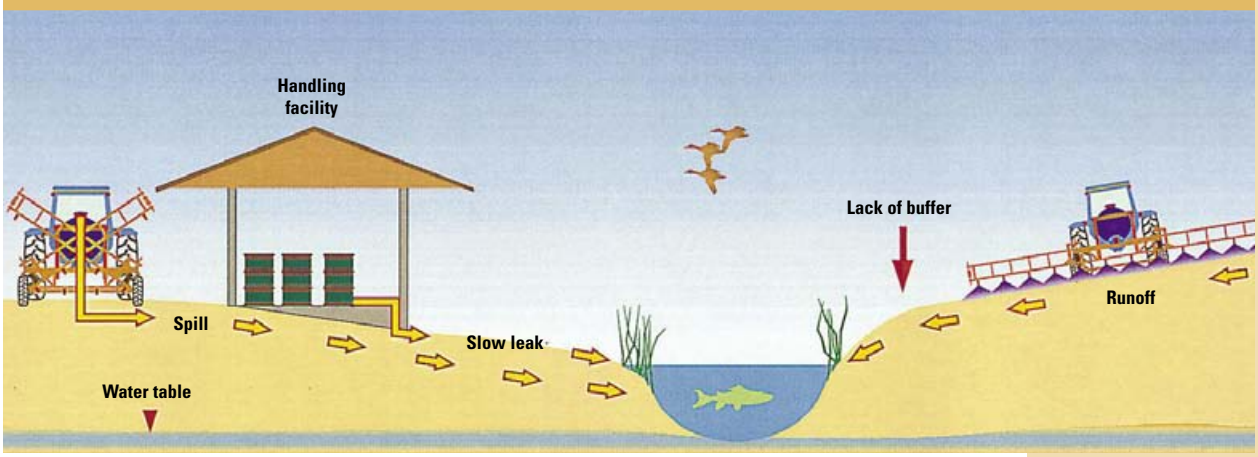
Pesticides and their breakdown products can contaminate surface water and groundwater resources by following the pathways of the water cycle or by artificial means. Therefore, care must be taken in areas of porous soil materials, shallow aquifers, poorly protected wells, and concentrated storage or use of pesticides.

Groundwater is recharged by surface water, precipitation, snowmelt, and irrigation waters that percolate through soil and geological materials. The more porous or fractured the materials and the shallower the groundwater resource (aquifer), the higher the rate of recharge.

Ponds and wells, including abandoned ones, not only access aquifers but can also provide direct conduits for infiltrating waters.

INTRODUCTION

POTENTIAL FOR SURFACE WATER CONTAMINATION



Surface waters can be contaminated by pesticides through leakage, spills, and surface runoff.

Not all water infiltrates the soil. About 10% runs off. Rates of runoff increase with slope, lower infiltration rates (e.g., clay soils), and higher volumes of water due to snowmelt, rainfall, and storms.

Sometimes, runoff from farmland will reach natural areas such as watercourses, ponds, and wetlands. There is a higher risk to natural areas when the rate of runoff is high, the distance from source is short, and there is no barrier in place to divert the flow. Some pesticides will follow this path of the water cycle: this is particularly a concern in the case of a spill. Some pesticides, like triazines, attach to soil particles and can contaminate natural areas if best management practices are not put in place to control erosion and reduce runoff.

The label instructions reflect all the known properties of the product. Follow the directions carefully to minimize risks to people, livestock, wildlife, and environmental concerns.

There are several production publications that address crop protection and use of pesticides. Many of these are updated annually with the latest recommendations for pesticides and related practices. For some crops (e.g., muck crops, apples), integrated pest management manuals are also available to assist growers in better managing pesticide use. A list of publications is provided on the back cover of this book.

INTRODUCTION

HAZARDS OF MOST COMMONLY USED PESTICIDES IN ONTARIO

				SOIL AND WATER		WILDLIFE TOXICITY			
PRODUCT NAME	**LABELLED SIGNAL WORD**	**WINTER STORAGE**	**LEACHING**	**ADSORP-TION**	**SOLUTION**	**MAMMALIAN TOXICITY**	**BIRDS**	**FISH**	**BEES**
HERBICIDES									
Metolachlor (Dual®)	Warning	B	L	M	L	LT	VLT	MT	NT
Atrazine (Aatrex®)	Caution	B	M	M	M	LT	LT	LT	NT
Glyphosate (Roundup®, Touchdown®)	Warning	B	L	H	H	LT	VLT	VLT	NT
2,4-D amines	Warning	A	M	L	M	MT	MT	VLT	NT
INSECTICIDES									
Azinphos-methyl (Guthion®, Sniper®)	Danger	A	L	M	H	VHT	HT	VHT	HT
Terbufos (Counter®)	Danger	C	L	L	M	ET	HT	MT	MT
Carbaryl (Sevin®)	Warning	A	L	L	M	MT	LT	MT	HT
Carbofuran (Furadan®)	Danger	A	H	M	H	ET	HT	HT	HT
Cypermethrin (Cymbush®)	Warning	A	VL	M	L	MT	VLT	MT	HT

INTRODUCTION

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FUNGICIDES									
Mancozeb (Dithane®, Manzate, Penncozeb®)	Caution	C	L	H	L	LT	LT	LT	NT
Sulfur	Caution	C	M	H	L	LT	VLT	VLT	NT
Myclobutinal (Nova®)	Caution	A	L	L-M	L	LT	LT	MT	NT
NEMATOCIDES									
1,3-dichloropropene (Telone®)	Danger	B	M-H	L	H	MT	MT	HT	NT
Methyl isothiocyanate (Vorlex®)	Danger	B	M-H	L	H	MT	MT	HT	NT

WINTER STORAGE

A – Do not allow to freeze.

B – Preferably should not freeze. If frozen, return to original state by allowing product to warm to 10-20°C and agitate thoroughly before use.

C – Not usually damaged by freezing. Store in a cool, dry place. Emulsifiable concentrate and solution formulations in this group are stable to -18°C. Dry flowable formulations packaged in water-soluble film should not be moved while frozen.

SOIL AND WATER RATINGS

VL – very low
L – low
M – moderate
H – high

MAMMALIAN TOXICITY (ORAL LD_{50} RATE mg/kg)

VHT (extreme toxicity) – 0-10
HT (high toxicity) – 11-100
MT (moderate toxicity) – 101-1000
LT (low toxicity) – 1001-10000
VLT (very low toxicity) – >10000

BIRDS (ACUTE ORAL mg/kg)

VHT – <10
HT – 10-50
MT – 51-500
LT – 501-2000
VLT – >2000

FISH (ppm)

VHT – <0.1
HT – 0.1-1
MT – 2-10
LT – 11-100
VLT – >100

BEES

HT: Kills on contact.
MT: Kills bees if applied over them.
NT: Relatively non toxic. Can be used with few precautions with minimum injury to bees.