Chapter 23
The Pesticide Dilemma

Pest Control

- Worldwide, pests destroy 1/3 of the world's potential food harvest.
- Pest - any organism that occurs where it is not wanted or that occurs in large enough numbers to cause economic damage.
- Many farmers rely on pesticides to produce their crops.
- Pesticide - poison used to destroy pests.
  - Insecticides, rodenticides, and herbicides
  - Can also harm beneficial plants and insects, wildlife, and even people.

The Ideal Pesticide

The ideal pest-killing chemical has these qualities:
- Narrow Spectrum - Kill only target pest.
- Doesn't cause genetic resistance in the target organism.
- Readily breaks down into harmless chemicals after doing its job.
- Non-mobile in environment
- Be more cost-effective than doing nothing.

Types of Pesticides

- Biological – Ladybugs, parasitic wasps, etc.
- Carbamates affect nervous system of pests more water soluble than chlorinated hydrocarbons
  - Aldicarb, aminocarb, carbaryl (Sevin), carbofuran, Mirex
- Chlorinated Hydrocarbons affect nervous system –
  - Aldrin, Chlordane, DDT, dieldrin, lindane and paradichlorobenzene
- Fumigants are used to sterilize soil and prevent grain infestation
- Inorganic – arsenic, copper, lead, mercury
  - Highly toxic and bioaccumulation
- Organic or natural — derived from plants such as tobacco and chrysanthemum
- Organophosphates — extremely toxic, low persistence
  - Malathion, parathion, chlorpyrifos, acepate, propetamphos and trichlorfon
**What is a Pesticide?**

**First-Generation Pesticides**
- Inorganic compounds (e.g., lead, mercury) – highly toxic & very stable in environment
- Botanicals (e.g., nicotine, pyrethrin) – readily break down, but highly toxic to aquatic organisms & bees

Pyrethrin is derived from chrysanthemum flowers.

**Second-Generation Pesticides**
- Synthetic botanicals (e.g., pyrethroids)
- DDT

**The Major Groups of Insecticides**
- Grouping based on chemical structure
  - Chlorinated hydrocarbon (e.g., DDT)
  - Organophosphates (e.g., malathion)
  - Carbamates (e.g., carbaryl)

**The Major Kinds of Herbicides**
- Classified by how they act & what they kill
  - Selective herbicides (e.g., 2,4-D – kills broad-leaved plants)
  - Nonselective herbicides (e.g., glyphosate, aka: Round-Up™)

**Benefits and Problems with Pesticides**

**Advantages**
- Save lives
- Increase food supplies
- Profitable to use
- Work fast
- Safe if used properly

**Disadvantages**
- Promote genetic resistance
- Kill natural pest enemies
- Create new pest species
- Pollute the environment
- Can harm wildlife and people

**Benefits and Problems with Pesticides**

**Benefit: Disease Control**

Location of malaria
**Benefit: Disease Control**

**Benefits and Problems with Pesticides**

**Benefit: Crop production**
- Farmers save ~$3 - $5 in crops for every $1 invested into pesticides
- High number of pests because agriculture is usually a monoculture.

**Problem: Evolution of Genetic Resistance**

- Genetic Resistance:
  - Pest populations may evolve resistance, the ability to survive exposure to a particular pesticide.
  - More than 500 species of insects have developed resistance to pesticides since the 1940s.

**Superpests**

- Superpests are resistant to pesticides.
- Superpests like the silver whitefly (left) challenge farmers as they cause > $200 million per year in U.S. crop losses.
Benefits and Problems with Pesticides

Problem: Evolution of Genetic Resistance

- Resistance Management
  - Create a “refuge” (no pesticide applied)
  - Interbreeding delays resistance
  - Avoid repeated use of same pesticide

Benefits and Problems with Pesticides

Problem: Imbalances in the Ecosystem

<table>
<thead>
<tr>
<th>Period</th>
<th>Insects</th>
<th>Diseases</th>
<th>Weeds</th>
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<tbody>
<tr>
<td>1989–1999</td>
<td>13.0</td>
<td>12.0</td>
<td>12.0</td>
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<tr>
<td>1974</td>
<td>13.0</td>
<td>12.0</td>
<td>8.0</td>
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<tr>
<td>1951–1960</td>
<td>12.9</td>
<td>12.2</td>
<td>8.5</td>
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<td>1942–1951</td>
<td>7.1</td>
<td>10.5</td>
<td>13.8</td>
</tr>
</tbody>
</table>

Table 23.1 Percentage of Crops Lost Annually to Pests in the United States

http://www.cbsnews.com/video/watch/?id=4901291n
**Benefits and Problems with Pesticides**

**Problem: Imbalances in the Ecosystem**

- Creation of New Pests

![Graph showing DDT treated trees versus untreated control trees.](image)

**Benefits and Problems with Pesticides**

**Problem: Persistence, Bioaccumulation, and Biological Magnification**

- Biomagnification of DDT

**Benefits and Problems with Pesticides**

- A pesticide is **persistent** if it does not break down easily or quickly in the environment.
  - They accumulate in the water and soil.
- Some pesticides have been banned in the United States for decades but can still be detected in the environment.

**Benefits and Problems with Pesticides**

**Problem: Mobility in the Environment**

![Pathway diagram showing various pesticide pathways.](image)

**Risks of Pesticides to Human Health**

- Pesticides are designed to kill organisms, so they may also be dangerous to humans.
- Cancer rates among children in areas where large amounts of pesticides are used on crops are sometimes higher than the national average.
- People who apply pesticides need to follow safety guidelines to protect themselves from contact with these chemicals.
Risks of Pesticides to Human Health

Short-term Effects of Pesticides
Handling of food with pesticide residue

Case-in-Point: The Bhopal Disaster
- 40 tons of methyl isocyanate gas released
- 600,000 people exposed
- 2,500 immediately killed
- 2,500 more killed through time
- 50,000-60,000 have serious health problems

Risks of Pesticides to Human Health

Long-term Effects of Pesticides
- Potentially higher risk of cancer
- Sterility
- Miscarriage / birth defects
- Potentially higher risk for Parkinson's disease

Alternatives to Pesticides

Using Cultivation Methods to Control Pests
- Interplant mixtures of plants
- Strip cutting
- Planting, fertilizing, and irrigating at proper time
- Crop rotation
Alternatives to Pesticides

• Biological Controls
  Using naturally occurring diseases, parasites, or predators to control a pest

Alternatives to Pesticides

• Biological control - use of certain organisms by humans to eliminate or control pests.
  • Includes the use of:
    • Pathogens
    • Plant defenses
    • Chemicals from plants
    • Disrupting of insect breeding

Alternatives to Pesticides

Biological pest control: Wasp parasitizing a gypsy moth caterpillar.

Alternatives to Pesticides

• Pheromones and Hormones
  Use pheromones to attract insects to traps
  Synthetic hormones induce abnormal development

Alternatives to Pesticides

• Reproductive Controls
  Sterile-male technique — inundate pest population with large numbers of sterile males

Alternatives to Pesticides

Genetic Controls

  Using Genetically Modified plants (GMOs)
  Case-in-Point: Bt, Its Potential and Problems
  Genetically modified corn to produce Bt toxin
  Potential problem: may affect non-target species, such as monarch butterfly
  Quarantine

Integrated Pest Management
Alternatives to Pesticides

A modern method of controlling pests on crops.

The goal isn’t to reduce pest damage to a level that causes minimal economic damage.

Programs include a mix of farming methods, biological pest control, and chemical pest control.

Parts of IPM

Polyculture instead of monoculture
Intercropping — alternate rows of crops that have different pests
Planting pest-repellent crops
Mulch to control weeds
Natural insect predators — ladybugs, preying mantis, birds
Rotating crops to disrupt insect cycles
Using Pheromones to attract insects to traps
Releasing sterilized insects

Alternatives to Pesticides

IPM practices for preventing pest damage:
Inspecting crops and monitoring crops for damage
using mechanical trapping devices
natural predators (e.g., insects that eat other insects)
insect growth regulators
mating disruption substances (pheromones)
if necessary, chemical pesticides

Alternatives to Pesticides

Sustainable agriculture - farming that conserves natural resources and helps keep the land productive.
It involves planting productive, pest-resistant crop varieties that require little energy, pesticides, fertilizer, and water.

Alternatives to Pesticides

Irradiating Foods
Predominantly used on meats
Kills many microorganisms
Pesticide Protection Laws in the U.S.

Government regulation has banned a number of harmful pesticides but some scientists call for strengthening pesticide laws.

The Environmental Protection Agency (EPA), the Department of Agriculture (USDA), and the Food and Drug Administration (FDA) regulate the sales of pesticides under the Federal Insecticide, Fungicide and Rodenticide Act (FIFRA).

The EPA has only evaluated the health effects of 10% of the active ingredients of all pesticides.

Laws Controlling Pesticide Use

Food, Drug, and Cosmetics Act (1938)
→ Pesticide Chemicals Amendment (1954)
→ Delaney Cause (1958)
Federal Insecticide, Fungicide, and Rodenticide Act (1947)
Food Quality Protection Act (1996)

Laws Controlling Pesticide Use

<table>
<thead>
<tr>
<th>Food</th>
<th>Cancer Risk*</th>
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<tbody>
<tr>
<td>Tomatoes</td>
<td>6.8 x 10^-4</td>
</tr>
<tr>
<td>Beef</td>
<td>6.5 x 10^-4</td>
</tr>
<tr>
<td>Potatoes</td>
<td>5.2 x 10^-4</td>
</tr>
<tr>
<td>Oranges</td>
<td>5.6 x 10^-4</td>
</tr>
<tr>
<td>Lettuce</td>
<td>5.4 x 10^-4</td>
</tr>
<tr>
<td>Apples</td>
<td>3.2 x 10^-4</td>
</tr>
<tr>
<td>Oranges</td>
<td>2.0 x 10^-4</td>
</tr>
<tr>
<td>Park</td>
<td>2.7 x 10^-4</td>
</tr>
<tr>
<td>Wheat</td>
<td>1.9 x 10^-4</td>
</tr>
<tr>
<td>Soybeans</td>
<td>1.3 x 10^-4</td>
</tr>
</tbody>
</table>

The Manufacture and Use of Banned Pesticides

Some US companies still make banned or seriously restricted pesticides and export the product. This can potentially lead to the importation of food tainted with banned pesticides.

The Global Ban of Persistent Organic Pollutants

<table>
<thead>
<tr>
<th>Persistent Organic Pollutant</th>
<th>Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aldrin</td>
<td>Insecticide</td>
</tr>
<tr>
<td>Chlordane</td>
<td>Insecticide</td>
</tr>
<tr>
<td>DDT (dichlorodiphenyltrichloroethane)</td>
<td>Insecticide</td>
</tr>
<tr>
<td>Dieldrin</td>
<td>Insecticide</td>
</tr>
<tr>
<td>Endrin</td>
<td>Insecticide</td>
</tr>
<tr>
<td>Heptachlor</td>
<td>Rodenticide and insecticide</td>
</tr>
<tr>
<td>Hexachlorobenzene</td>
<td>Fungicide</td>
</tr>
<tr>
<td>Mirex*</td>
<td>Insecticide fire retardant</td>
</tr>
<tr>
<td>Tosepane™</td>
<td>Insecticide</td>
</tr>
<tr>
<td>PCBs (polychlorinated biphenyls)</td>
<td>Industrial chemical</td>
</tr>
<tr>
<td>Dioxin</td>
<td>By product of certain manufacturing processes</td>
</tr>
<tr>
<td>Furans (dibenzofurans)</td>
<td>By product of certain manufacturing processes</td>
</tr>
</tbody>
</table>

* Estimates of Risk of Cancer from Pesticide Residue

The Manufacture and Use of Banned Pesticides

The Global Ban of Persistent Organic Pollutants