Fate of Pesticides in Soil

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Topics to be covered

- What Happens after Pesticides Application?
- Pesticide Movement
- Degradation or Breakdown Processes
- Pesticide Characteristics
- Ways to Minimize Pesticide Impact

What Happens to Pesticides?

Beneficial effects

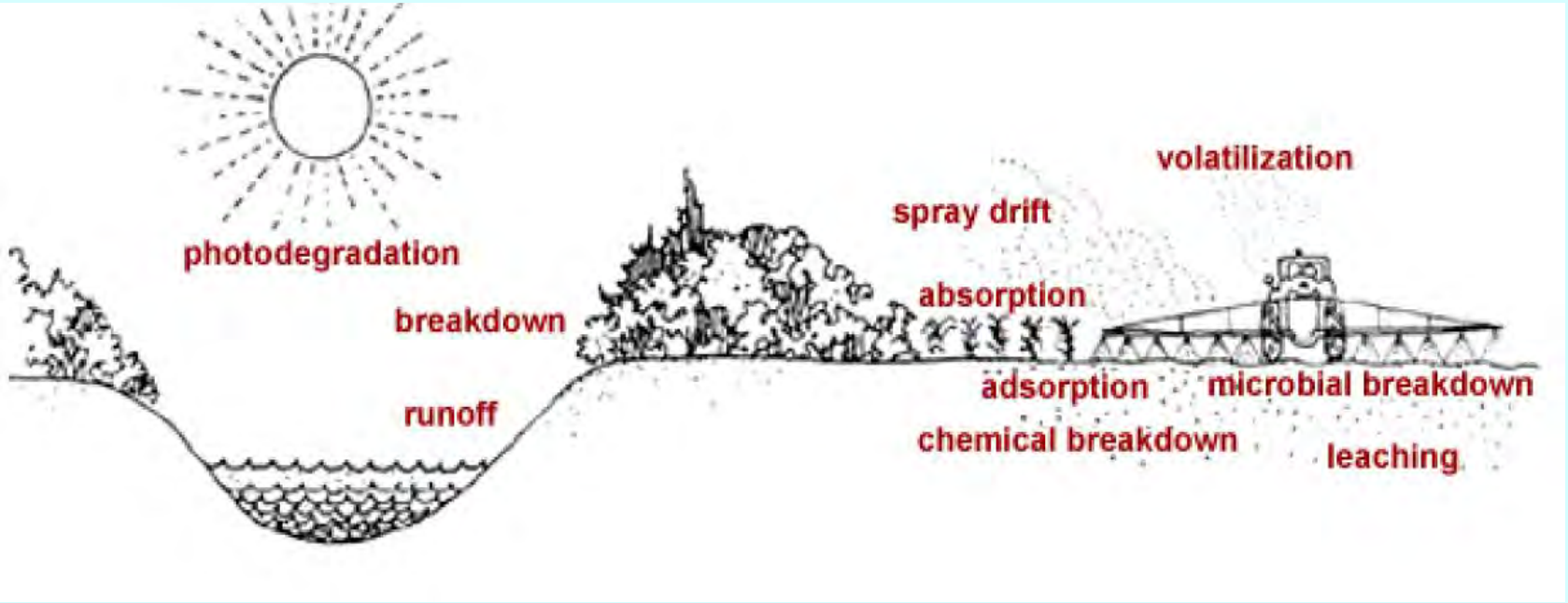
- Pest in question is controlled
- Herbicide leached into root zone to control weeds
- Farm income improved due to increased yields
- Relatively low food cost
- Human health can be enhanced

What Happens to Pesticides?

Unintended consequences

- Not all of the applied chemical reaches the target site
- Ineffective control because of drift and leaching losses
- May harm other plants and animals that were not targeted
- May cause pollution of surface and ground water
- Pesticide residues may enter the food chain

Fate of applied pesticides



Why are we concerned?

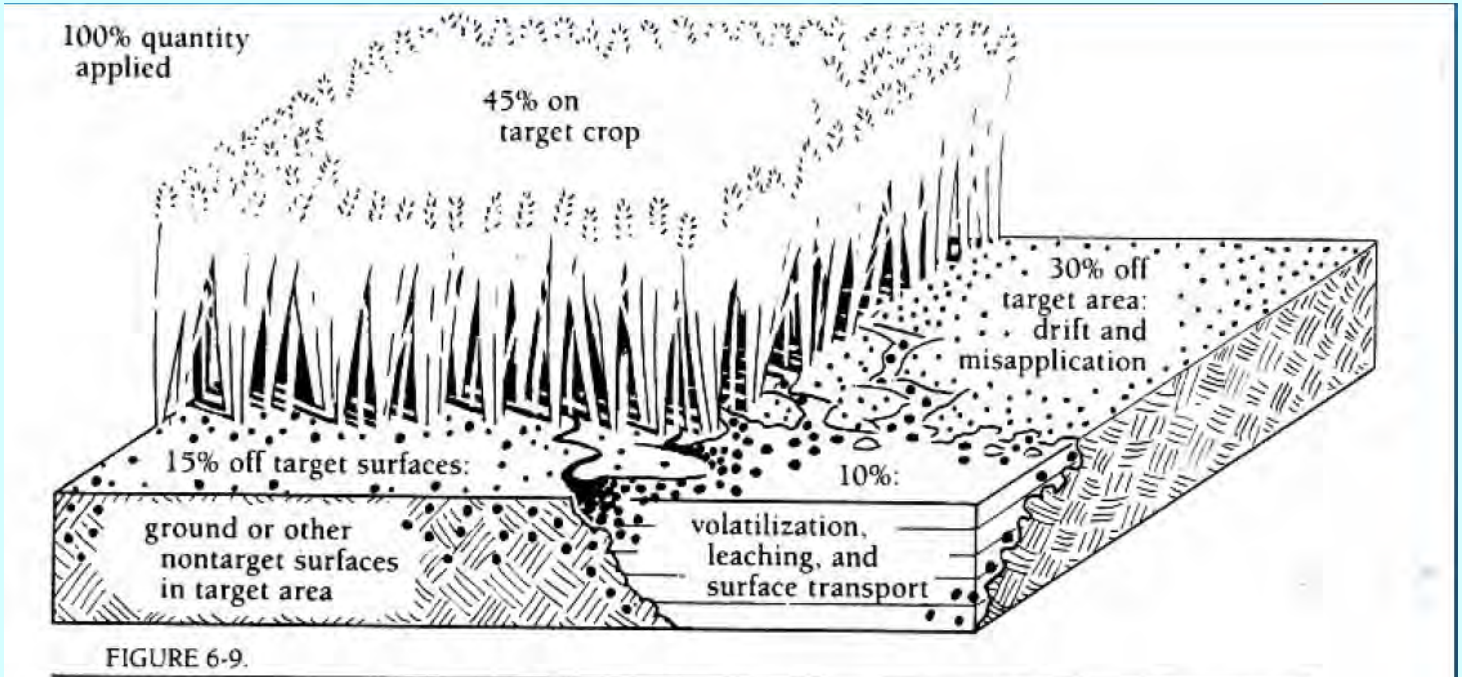


FIGURE 6-9.

As much as 55% of an applied pesticide may leave the application site due to spray drift, volatilization, leaching, runoff, and soil erosion.

Pesticide Movement

Pesticides can be mobile and subject to different processes in the environment

Called "**Transfer Process**"

- **Adsorption**
- **Volatilization**
- **Spray drift**
- **Runoff**
- **Leaching**
- **Crop removal**

Adsorption

Binding of pesticides to soil particles

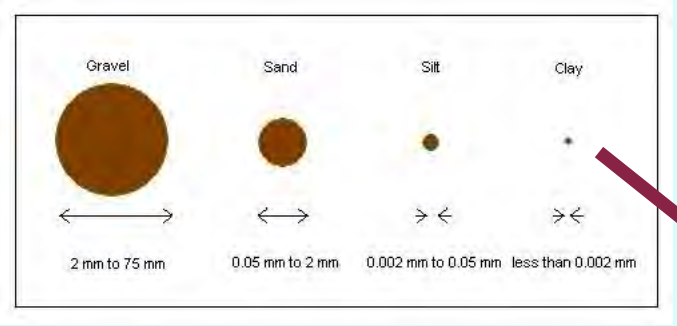
Depends on

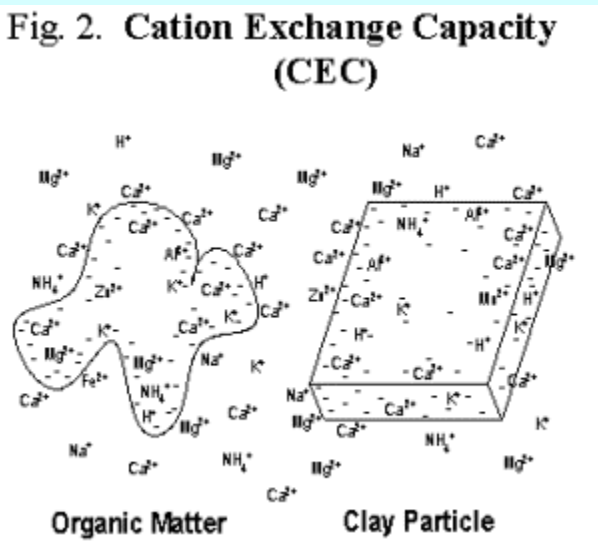
- **Pesticide**
- **Soil**
- **Moisture**
- **Soil pH**
- **Soil texture**

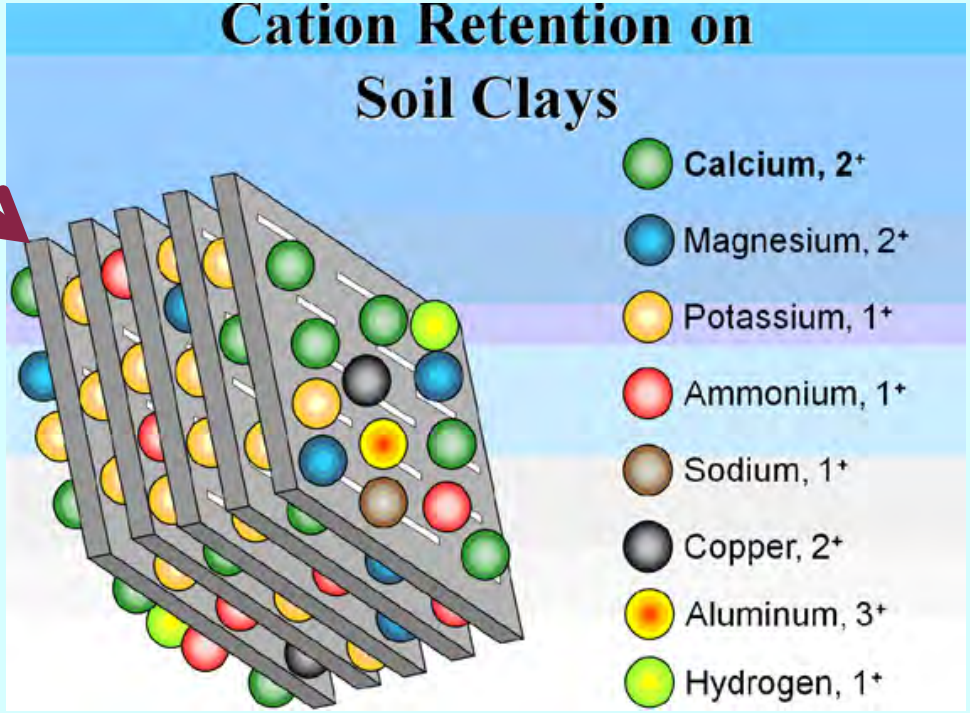
Pesticides are strongly adsorbed to soils that are **high in clay** or **organic matter** but not to **sandy soils.**

Clay Particles and Organic Matter

- Clay Particles/Organic Matter are very reactive
- They have negative charges







Impact of Adsorption

Soil-bound pesticides

- less likely to give off vapors or leach through the soil
- Less likely to affect plants

In some cases, when soil is high in clay or organic matter, **higher pesticide rates** may be needed for effective control

Volatilization

Solids or liquids converted into a gas

- Movement from the application site
- Can damage nearby crops
- Volatilization more in wet and sandy soils
- Hot, dry and windy weather favor volatilization
- Small spray drops also favor volatilization
- Pesticide incorporation into soil can reduce volatilization

Spray Drift

Movement of airborne droplets away from treatment sites during application

- **spray droplet size** - the smaller the droplets, the more likely they will drift
- **wind speed** - the stronger the wind, the more pesticide spray will drift
- **distance between nozzle and target plant or ground** - the greater the distance, the more the wind can affect the spray

Effect of Spray Drift

- Reduces the effectiveness of treatment
- Can damage nearby sensitive crops
- Can humans living close
- Can affect domestic animals
- Can affect pollinating insects
- Can cause general pollution

Runoff

Movement of pesticides in surface water over a sloping surface

Runoff occurs when rainfall or irrigation exceed infiltration (soil water intake)

Amount of pesticide in runoff depend on:

- Slope
- Soil texture
- Soil moisture content
- Amount and timing of a rain-event (irrigation or rainfall)
- Type of pesticide used

Minimizing Runoff Effect

- Using minimum tillage techniques to reduce soil erosion
- Grading surface to reduce slopes
- Leaving border vegetation and plant cover to contain runoff
- Use weather forecast to avoid spraying before heavy rainfall

Leaching

- Movement of pesticides in water through the soil
- Leaching can occur downwards, upwards and sideways
- **Leaching is increased when:**
  - Soil is sandy (water moves faster through soil)
  - Rain/irrigation event occurs shortly after spraying
  - **Pesticide is water soluble**
  - **Pesticide is not strongly adsorbed to the soil**

Soil Leaching Potential

Soil factors affecting pesticide leaching

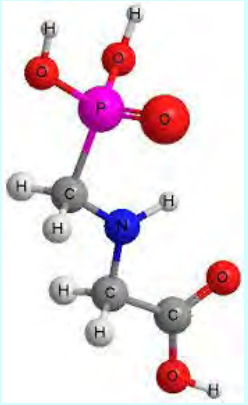
- **Organic Matter**
- **Texture**
- **Soil structure – relates the soil porosity**
- **Soil compaction**
- **pH**
- **Preferential flow – cracking soils**

Breakdown and Degradation

- Chemical Breakdown
- Photo-degradation
- Microbial Breakdown

Chemical Breakdown

Breakdown of pesticides due to chemical reactions in the soil



Affected by:

- Binding of pesticides to the soil
- Soil temperatures
- pH levels - Many pesticides, especially the organophosphate insecticides, break down more rapidly in alkaline
- Moisture

Photo-degradation

Breakdown of pesticides by sunlight

Photo-degradation affected by:

- Intensity and spectrum of sunlight
- Length of exposure,
- Properties of the pesticide

Foliage applied pesticides more susceptible to photo-degradation than soil incorporated pesticide

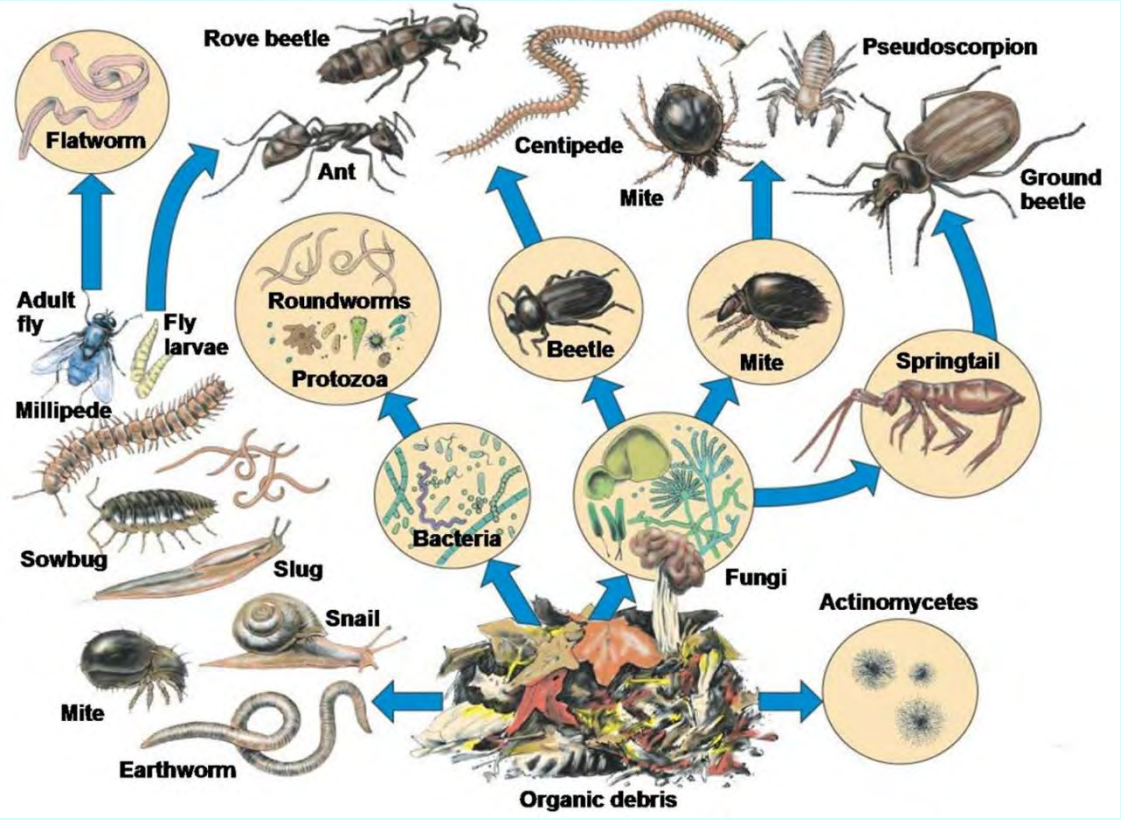
Crop Removal

- Harvest of crop for food or forage

- Grazing of animals may remove pesticide residues

Biological Breakdown

- Happens mostly in the soil
- A healthy soil is active and full of life



Soil Biology: Organisms

- Those we can see with our eyes
  - Earthworms
  - Insects
  - Burrowing animals
- Those we cannot see with our eyes
  - Bacteria
  - Fungi
  - Actinomycetes
  - Nematodes
  - Protozoa

Soil Organisms

In one teaspoon of soil

- Bacteria — 100 million to 1 billion
- Fungi — 6-9 ft fungal strands put end to end
- Protozoa — Several thousand flagellates & amoeba
  One to several hundred ciliates
- Nematodes — 10 to 20 bacterial feeders and a few fungal feeders
- Arthropods — Up to 100
- Earthworms — 5 or more

Effect of pesticides on soil organisms

- No generalized effect can be assumed
- Complex interaction between active substances and soil organisms
- Some effects are temporary while some last longer
- Some agents can act positively on soil organisms while some are negative
- Some pesticides don’t have any effect at all
- Same pesticide can affect a soil organism differently in varied soil type
- Temporary changes in count and/or diversity may occur

Table 1 Effect of pesticides on soil microorganisms

Pesticide	Microbial species	Comments	References
Atrazine, isoproturon, metribuzin, and sulfosulfuron	*Bradyrhizobium* sp.	Adversely affected *Bradyrhizobium* sp.	Khan *et al.* (2006)
Phorate, carbofuran, carbosulfan, thiamethoxam, imidacloprid, chlorpyrifos, monocrotophos	Soil microflora	No significant change in total viable count of bacteria	Sarnaik *et al.* (2006)
Methamidophos	Soil microflora	Decreased microbial biomass (41–83%)	Wang *et al.* (2006)
Metsulfuron methyl	Soil microorganisms	Inhibited heterotrophic S-oxidizing and S-reducing bacteria but increased fungi	He *et al.* (2006)
Metalaxyl	Microbial biomass	Decreased microbial biomass	Sukul and Spiteller (2001)
Mefenoxam, metalaxyl	Soil microorganisms	Inhibited N-fixing bacteria	Monkiedje *et al.* (2002)
Carbendazim, imazetapir, thiram	Soil microorganisms	Combination of fungicide and herbicide reduced while herbicide alone increased soil microorganisms	Niewiadomska (2004)
Carbofuran, ethion, hexaconazole	Soil microorganisms	Adversely affected soil microorganisms	Kalam and Mukherjee (2001)
Bensulfuron methyl, metsulfuron methyl	Microbial biomass	Decreased microbial biomass-C, and N	El-Ghamry *et al.* (2001)

Hussain et al. 2009. Impact of Pesticides on Soil Microbial Diversity, Enzymes and Biochemical Reactions. Advances in Agronomy vol. 102: 159-200.

Important Conclusions

- It is difficult to comprehend the effect of pesticides on soil organisms due to divergent research findings.
- No definite conclusion can be made on the effect of pesticides on microorganisms
- In analyzing the effect of pesticides on soil organisms, factors such as **soil type**; **nature and concentration of pesticide**; **initial level and diversity of microbes**; and **weather conditions** complicate response obtained.

Bottom line

- Rate of application is important
- Frequency of application is important
- Effect of combination of chemicals may be different from individual chemicals
- Avoid spillage
- Use it the right way!!!!

Pesticide Characteristics

Pesticide characteristics important in for fate of the chemicals in the environment

Important characteristics are:

- Solubility in water
- Tendency to adsorb to the soil (soil adsorption)
- Pesticide persistence in the environment (half-life)

Pesticide Leaching Potential

Pesticide Leaching Potential (PLP)

$$\mathbf{PLP = (T_{1/2} \times R \times F)/Koc}$$

$T_{1/2}$ = Persistence of the pesticide, measured as half-life in days (Half life = time for 50% disappearance of pesticide)

R = Rate of application (pounds of active ingredient per acre)

F = Fraction of pesticide reaching the soil during application (1 for soil applications, less for post-emergence applications, depending on row width and canopy size.)

Koc = Affinity for soil particles (adsorption)

Half-lives of some common pesticides (in days)

- **2,4-D = 10**
- **Banvel /Clarity (dicamba) = 14**
- **Ally (metsulfuron) = 30**
- **Stinger (clopyralid) = 40**
- **Assert (imazamethabenz) = 45**
- **Roundup (glyphosate) = 47**
- **Spike (tebuthiuron) = 360**
- **Paraquat = 1,000**

The longer the half-life, the greater the potential for pesticide movement
Cutoff: >21 days

Pesticide Persistence in Soil

Grouping of pesticides based on persistence in soils.

Non-Persistent (half-life less than 30 days)	**Moderately Persistent** (half-life greater than 30 days, less than 100)		**Persistent** (half-life greater than 100 days)
Aldicarb	Aldrin	Heptachlor	Bromacil
Captan	Atrazine	Linuron	Chlordane
Dalapon	Carbaryl	Parathion	Lindane
Dicamba	Carbofuran	Phorate	Paraquat
Malathion	Diazinon	Simazine	Picloram
Methyl parathion	Endrin	Terbacil	Trifluralin
Oxamyl	Fonofos	TCA	
2, 4-D	Glyphosate		
2, 4, 5-T			

K_{OC} of some common pesticides

Affinity for soil particles

- Banvel (dicamba)= 2
- Stinger (clopyralid)= 6
- Pursuit (imazethapyr)= 10
- Assert (imazamethabenz) = 50
- 2,4-D = 20

- Treflan = 7,000
- Roundup (glyphosate) = 24,000 *
- Buctril (bromoxynil) = 10,000
- Capture (bifenthrin) = 216,500
- Paraquat =1,000,000 *

Low values (< 500)
Pesticides tend to move with water and can leach or move with surface runoff

High values (> 1000):
Pesticide that is very strongly attached to soil and is less likely to move unless soil erosion occurs

* Highly soluble in water

SLP & PLP for Risk Assessment

Pesticide Leaching Potential (PLP) Rating	Soil Leaching Potential (SLP) Rating				
	0–19 Very Low	20–39 Low	40–59 Moderate	60–79 High	80–100 Very High
0–19 Very Low	Very Low Risk	Very Low Risk	Very Low Risk	Low Risk	Low Risk
20–39 Low	Very Low Risk	Low Risk	Low Risk	Moderate Risk	Moderate Risk
40–59 Moderate	Very Low Risk	Low Risk	Moderate Risk	High Risk	High Risk
60–79 High	Low Risk	Moderate Risk	High Risk	Very High Risk	Very High Risk
80–100 Very High	Low Risk	Moderate Risk	High Risk	Very High Risk	Very High Risk

Groundwater Contamination Potential as Influenced by Water, Pe and Soil Characteristics

	Risk of Groundwater Contamination	
	Low risk	**High risk**
Pesticide characteristics		
Water solubility	low	high
Soil adsorption	high	low
Persistence	low	high
Soil characteristics		
Texture	fine clay	coarse sand
Organic matter	high	low
Macropores	few, small	many, large
Depth to groundwater	deep (100 ft. or more)	shallow (20 ft. or less)
Water volume	**small volumes**	**large volumes**
Rain/irrigation	infrequent intervals	frequently

Based on: McBride, D. K.

Minimizing Pesticide Impact

Integrated Pest Management

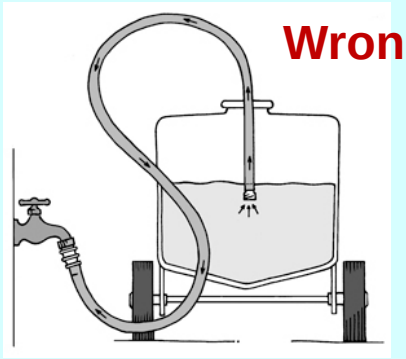
To achieve necessary level of control

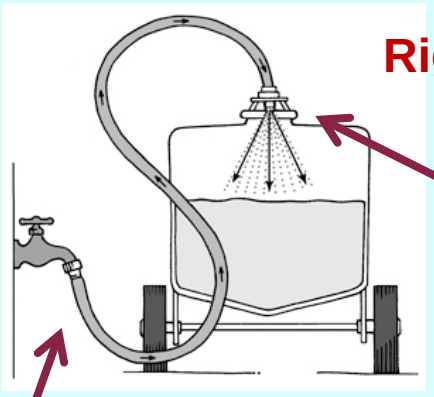
- **Biological control**
- **Cultural practices**
- **Timely chemical applications**

Simple Measures are Helpful

Prevent back-siphoning and spills

- Never allow a hose used for filling a spray tank to extend below the level of the water in the tank and
- Use anti-siphon devices





- Contain all spills as quickly as possible and handle according to label directions

Pesticide use and storage

- Read the label directions on container
- Use pesticide only when economic thresholds are reached
- Use appropriate protective equipment and clothing
- Avoid mixing pesticides near wells or water sources
- Store pesticide safely according to legal requirements and label directions
- Maintain application equipment and calibrate regularly

Disposal of excess pesticides

- Dispose excess pesticides and pesticide containers according to the label directions
- Triple-rinse empty pesticide containers
- Punch holes in containers
- Dispose them at the appropriate disposal sites

Consider weather and irrigation plans

- Use weather forecast to plan application program
- Time application to be compatible with irrigation
- Avoid application when rain is coming
- Avoid application when wind favors drift
- Use appropriate nozzle to minimize drift


Thanks