# Effect of Soil, Environment, and Chemistry on Herbicide Persistence

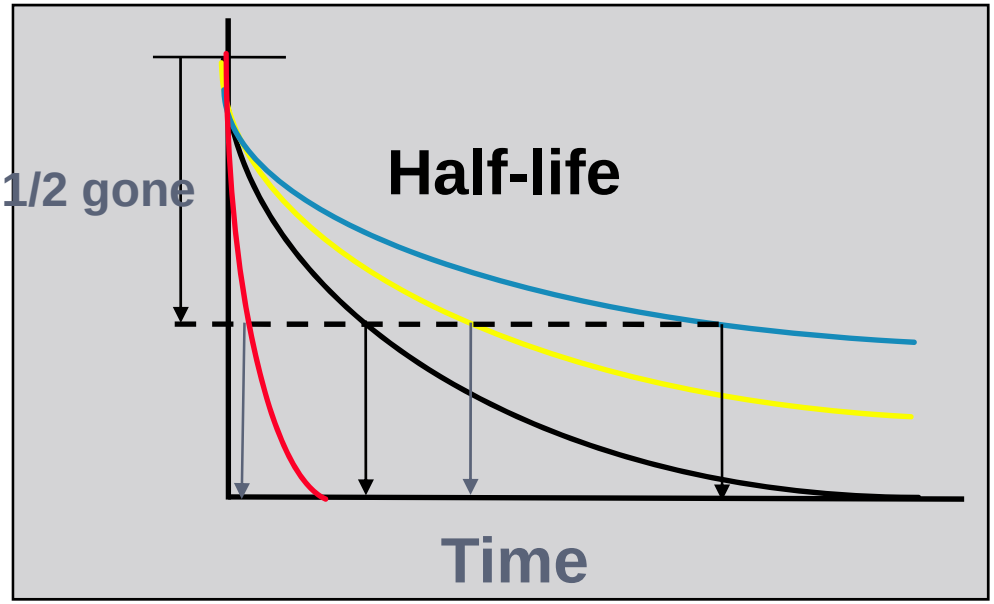
Brad Hanson
UC Davis Weed Science

bhanson@ucdavis.edu

Salinas Valley Weed School
November 9, 2010

# Herbicide Persistence

- The length of time that a herbicide (or its degradation products) remain in biologically significant amounts in the zone of application



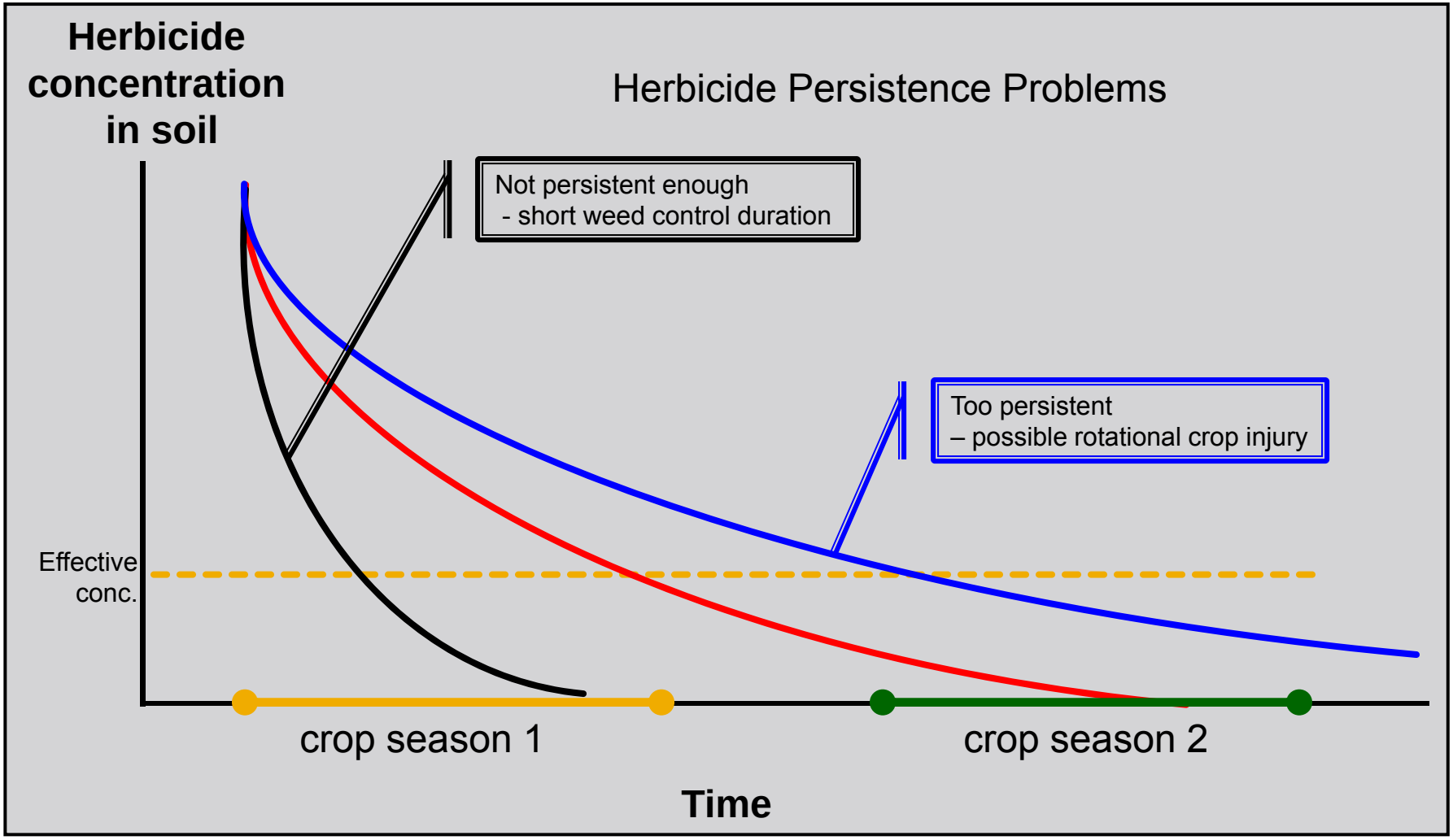
# Persistence: Why Do We Care?

- Herbicides must:
  - Persist long enough to control weeds
  - Dissipate fast enough to avoid rotational crop injury
  - Degrade fast enough to avoid environmental damage

Contact vs soil active – 4 MAT

Carryover in cover crop after vineyard

# Soil Active Herbicides



# Herbicide Dissipation

- Herbicide dissipation is affected by two types of processes
  - Transfer processes
    - Change in location or availability of the herbicide – NO change in chemical structure or properties
  - Degradation processes
    - Changes in the chemical structure of the compound which alters the potency of the herbicide

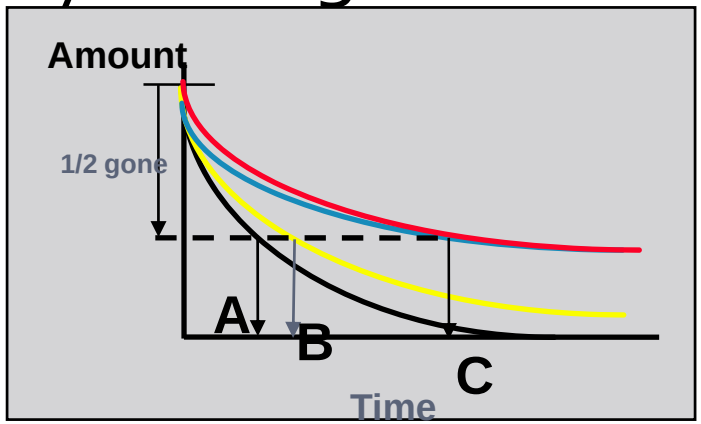
# Major Transfer Processes

- Physical drift
- Volatilization
- Adsorption to soil
- Leaching in soil
- Surface erosion
- Plant or animal uptake and removal

***Change in location or availability of the herbicide**

# Degradation

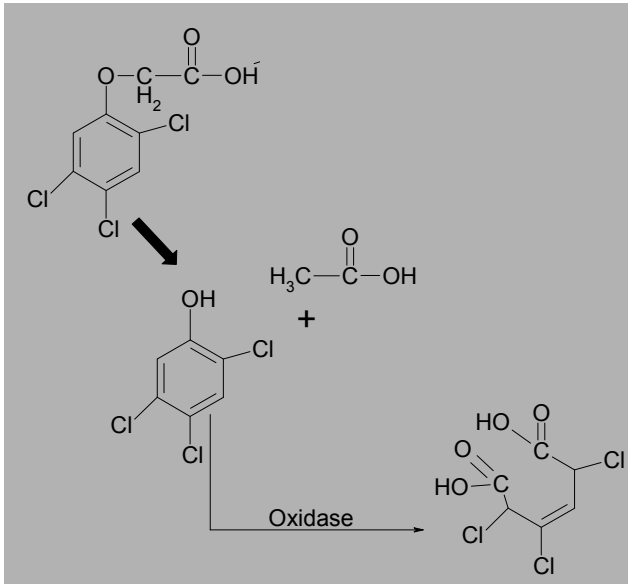
- Begins immediately after application and continues until broken down into molecules like $CO_2$ and $H_2O$
- ALL herbicides are degraded in the environment
- The degradation RATE can vary among herbicides
  or environments



# Degradation Processes

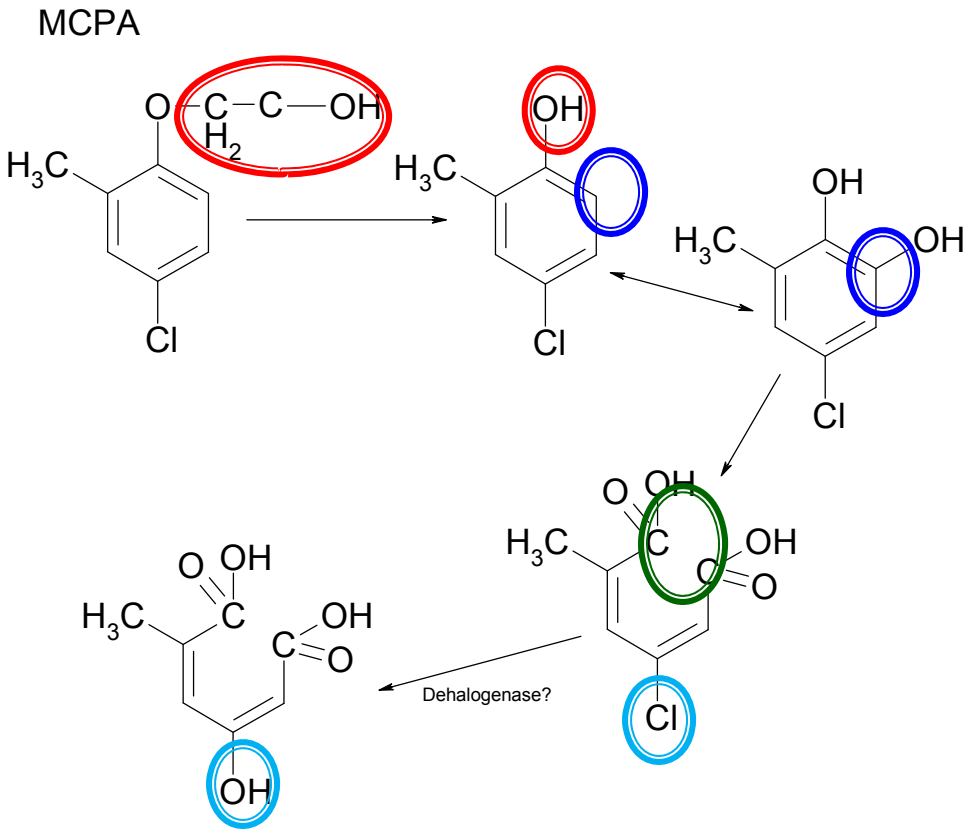
- Photochemical
- Chemical (in soil or water)
- Microbial (in soil or water)
- Plant/animal metabolism

***Changes in the chemical structure of the compound**



# Degradation Reactions

- Numerous types of reactions
  - Dehalogenation
  - Dealkylation
  - Decarboxylation
  - Oxidation
  - Hydrolysis
  - Conjugation
  - Ring cleavage
  - etc



# Photochemical Degradation

- Occurs due to destruction of chemical bonds by UV radiation
- On soil surface or in water
  - Some products formulated with "sunscreen" to minimize this
- Affected by:
  - Herbicide structure
  - Duration of exposure
  - Time of year

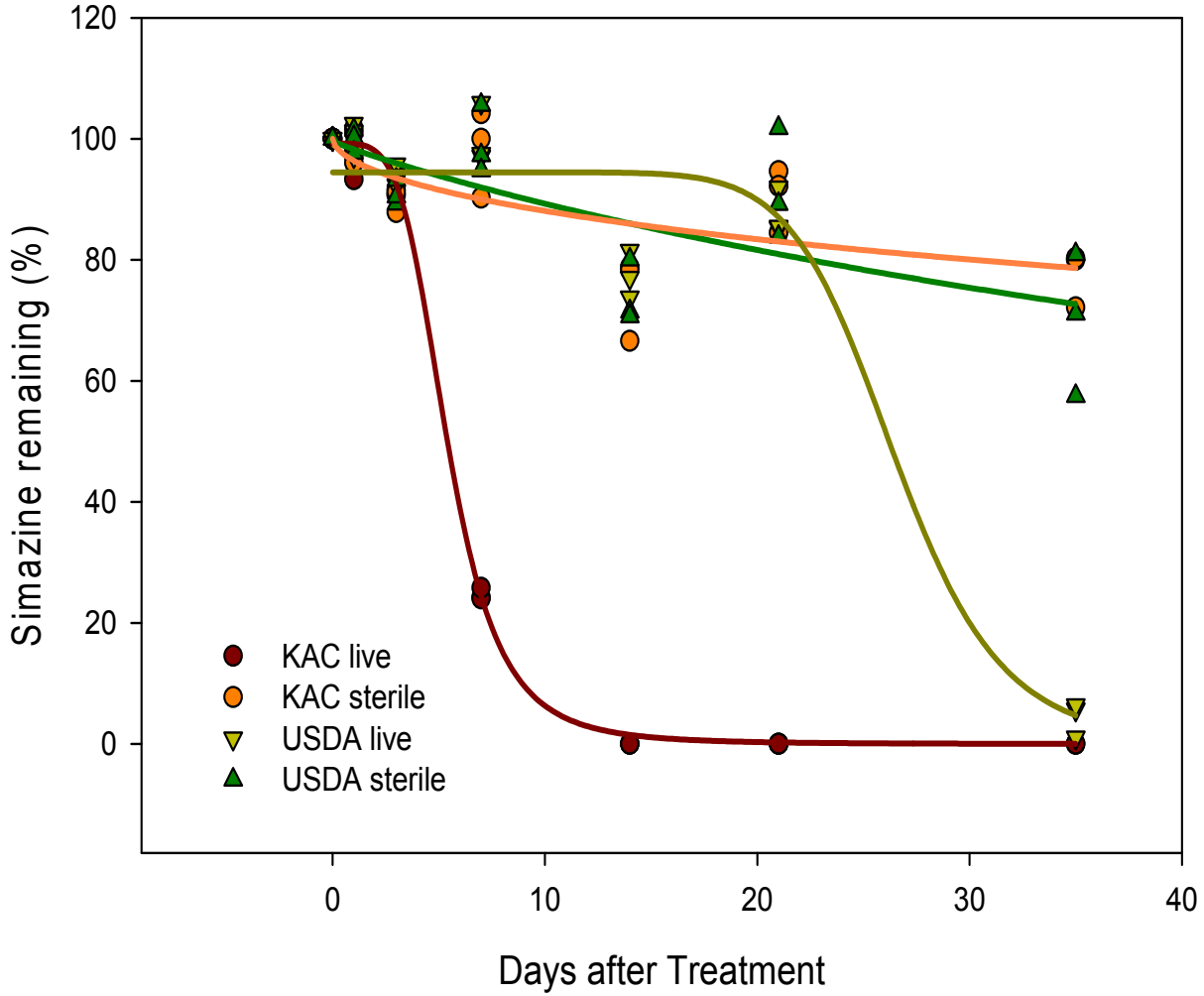
# Chemical Degradation

- Change in structure due to non-biological factors in soil or water
  - Ex. Hydrolysis: molecule reacts with water
- Factors affecting:
  - Soil or water pH
  - Temperature
  - Clay and organic matter content
  - Water content of soil
  - Chemical structure
    - Rings vs chains, functional groups

# Microbial Degradation

- Change in structure due to activity of microorganisms
  - Microbes produce enzymes that degrade the compounds
  - Organisms use the molecule as food source
- Usually not specific, but sometimes can be
  - Enhanced degradation
- Overall, the most important degradation process for herbicides

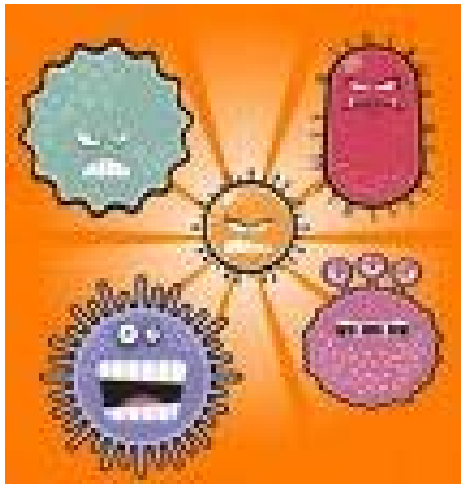
# Effect of Soil Sterilization on Herbicide Degradation



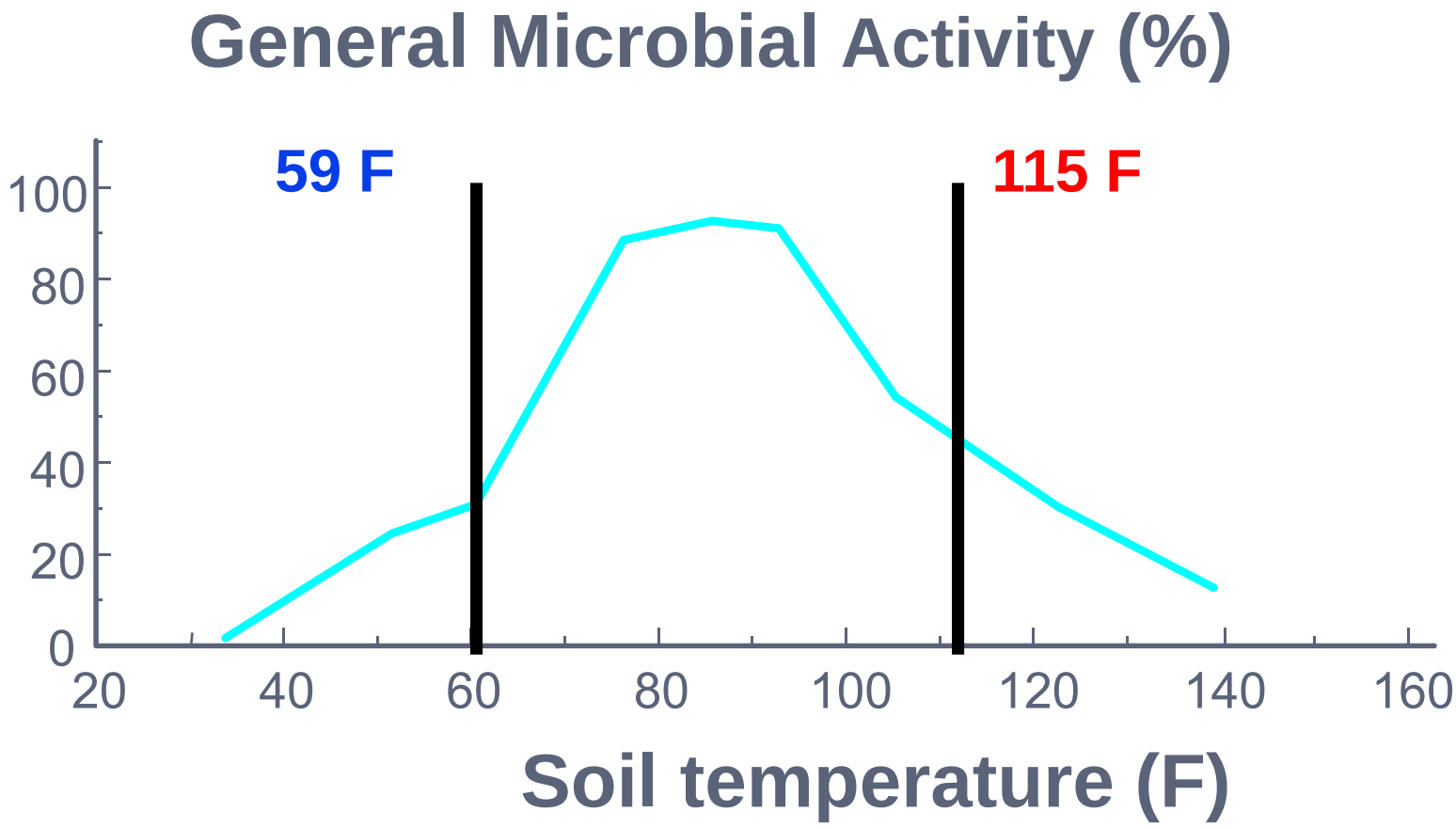

Rainbolt et al. 2009

# Microbial, cont.

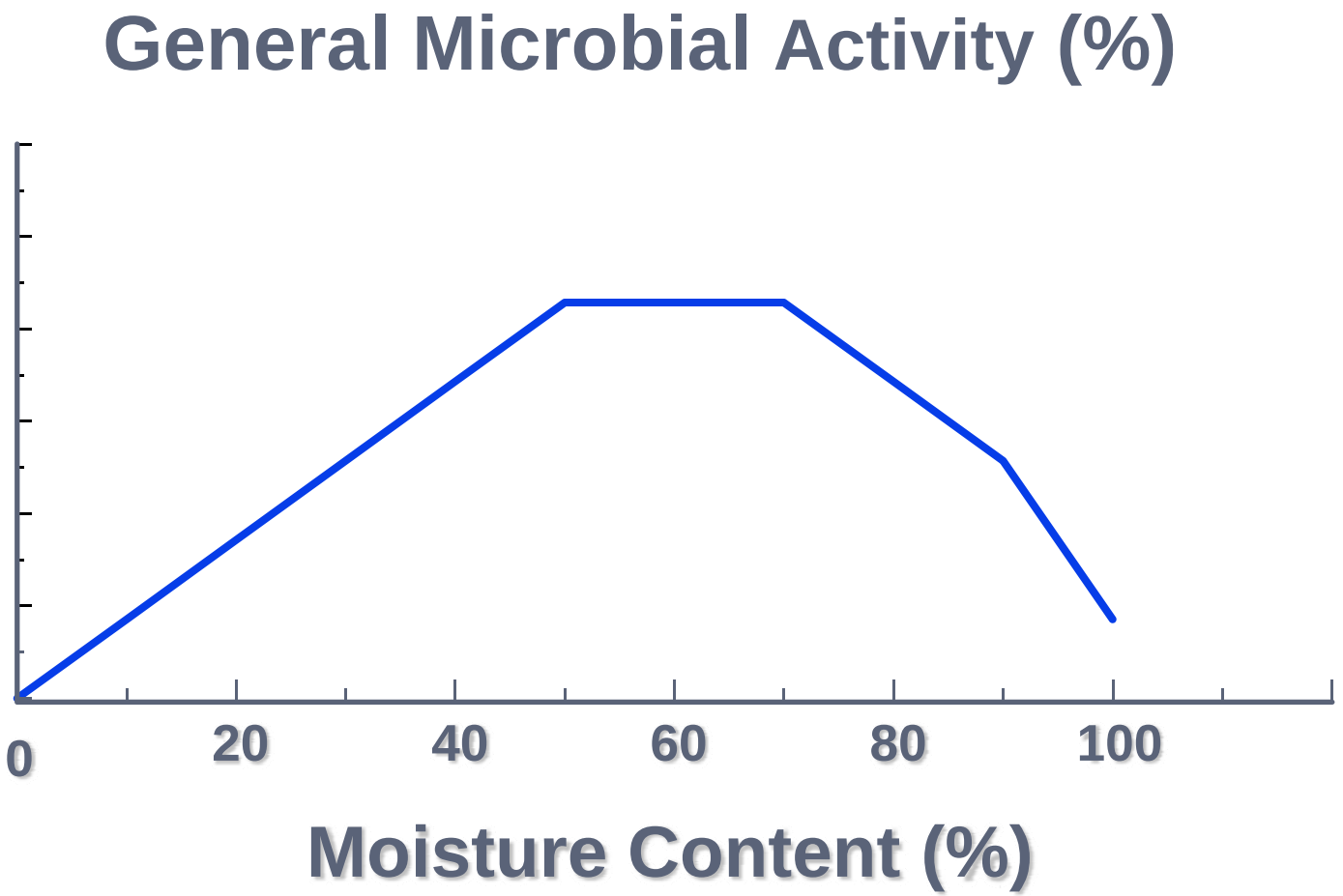
- Highest microbial levels in upper soil layers
- Factors affecting microbial activity (and thus degradation)
  - Temperature
  - Organic matter
  - Nutrient content
  - Soil or water pH
  - Water content of soil



# Temperature and Microbial Activity



# Soil Moisture and Microbial Activity



# Relative Persistence - Interactivity

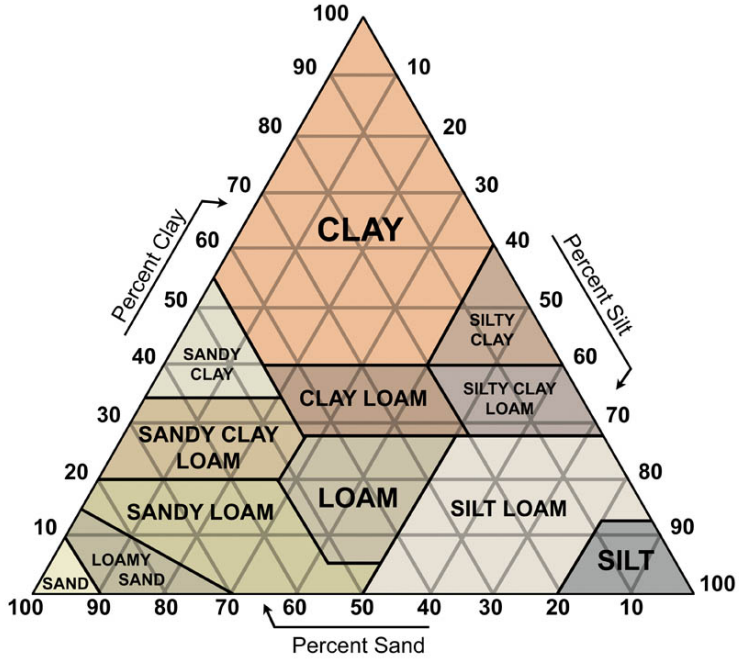
- Consider how soil, environmental, and herbicide chemistry affect chemical and microbial degradation and transfer processes

# Soil Factors

- Soil is a complex matrix with physical and chemical properties that affect herbicide dissipation
- Made up of various physical fractions
  - Mineral (soil texture)
  - Organic (living and decaying)
  - Water
  - Air space

# Soil Texture

- Water holding capacity
- Hydraulic conductivity
- Macro and micropore spaces

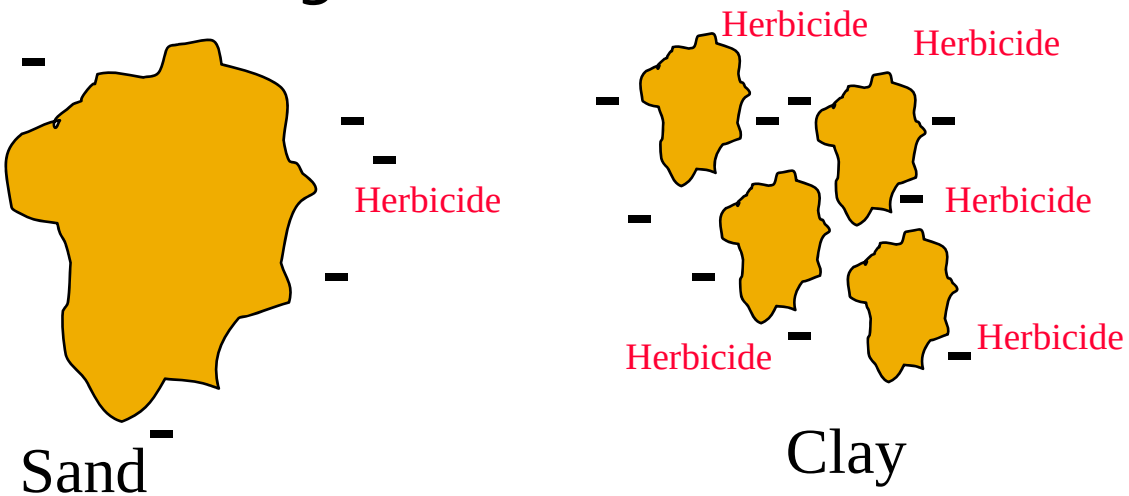


# Soil Chemistry

- pH (pKa of herbicides)
- CEC (cation exchange capacity)
  - Negative charge of soil
    - Clay and OM have more than sand
    - Influenced by type and amount of clay

# Chemistry and Texture

- Surface area of soil particles
  - Sand ~ 90 cm2 / gram
  - Silt ~ 450 cm2 / gram
  - Clay ~ 8,000,000 cm2 / gram



# Reactive Sites

Carbon-seeding grass seed, then treating with diuron

Examples:
-Carbon-seeding
-Fly ash applic.
-burn piles
-high OM soils

# Soil Moisture and Temperature

- Moisture
  - Irrigation vs dryland
  - Wetting and drying cycles
  - Saturated zones (anaerobic)
- Temperature
  - Application timing
  - Weather events
  - Mulches?

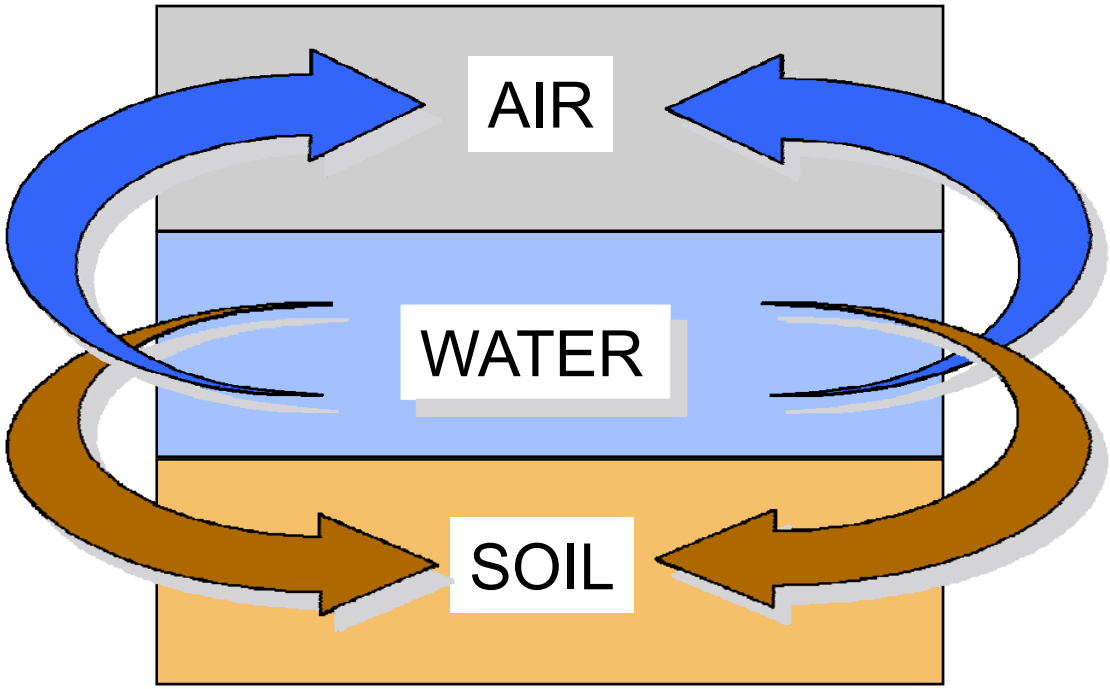
# Herbicide Availability

**Henry's Law Constant**
- Related to solid:gas phase equilibrium

$K_H$

**Sorption (distribution) Coefficient**
- Related to liquid:solid phase equilibrium

$K_D$




$K_{OW}$

**Octanol:Water Coefficient**
- Related to polar:non-polar equilibrium
  Hydrophobic vs lipophyllic

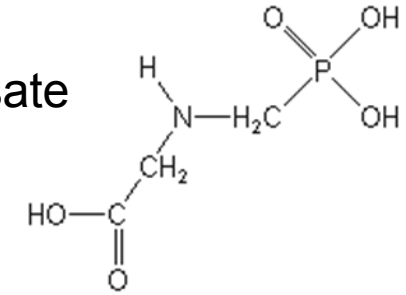
$K_{OC}$

**Organic Carbon:Water Partitioning Coefficient**
- Related to liquid:solid phase equilibrium (Kd) but normalized for carbon content

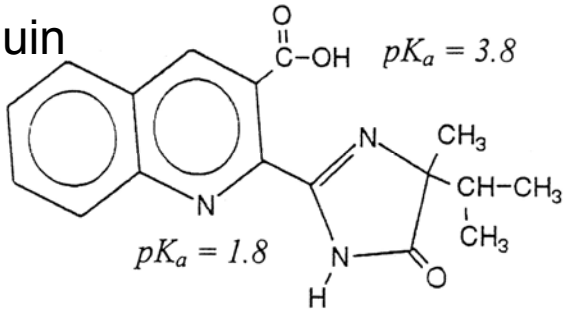
# Herbicide Chemistry / Structure

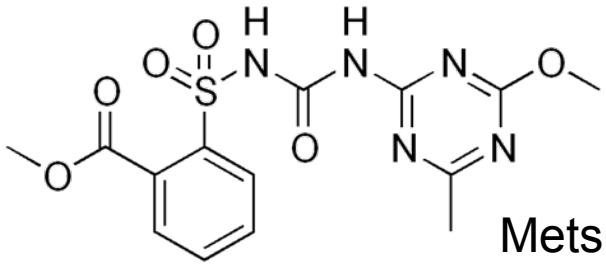
- Structure affects availability (sorption) and stability
  - Some molecules are inherently more/less stable than others
    - Ionizable groups
    - Rings vs chains
    - Various side chains????

glyphosate




imazaquin




Metsulfuron-methyl

# Adsorption

- Binding of herbicide to clay or OM
  - May be permanent or reversible
  - Can increase or decrease persistence
    - If strongly sorbed, not available for plant uptake OR degradation
- Affected by:
  - Herbicide structure
    - Charge, ionizable groups, Koc
  - Organic matter content
    - Reactive sites
  - Clay type and content
  - Soil pH and moisture

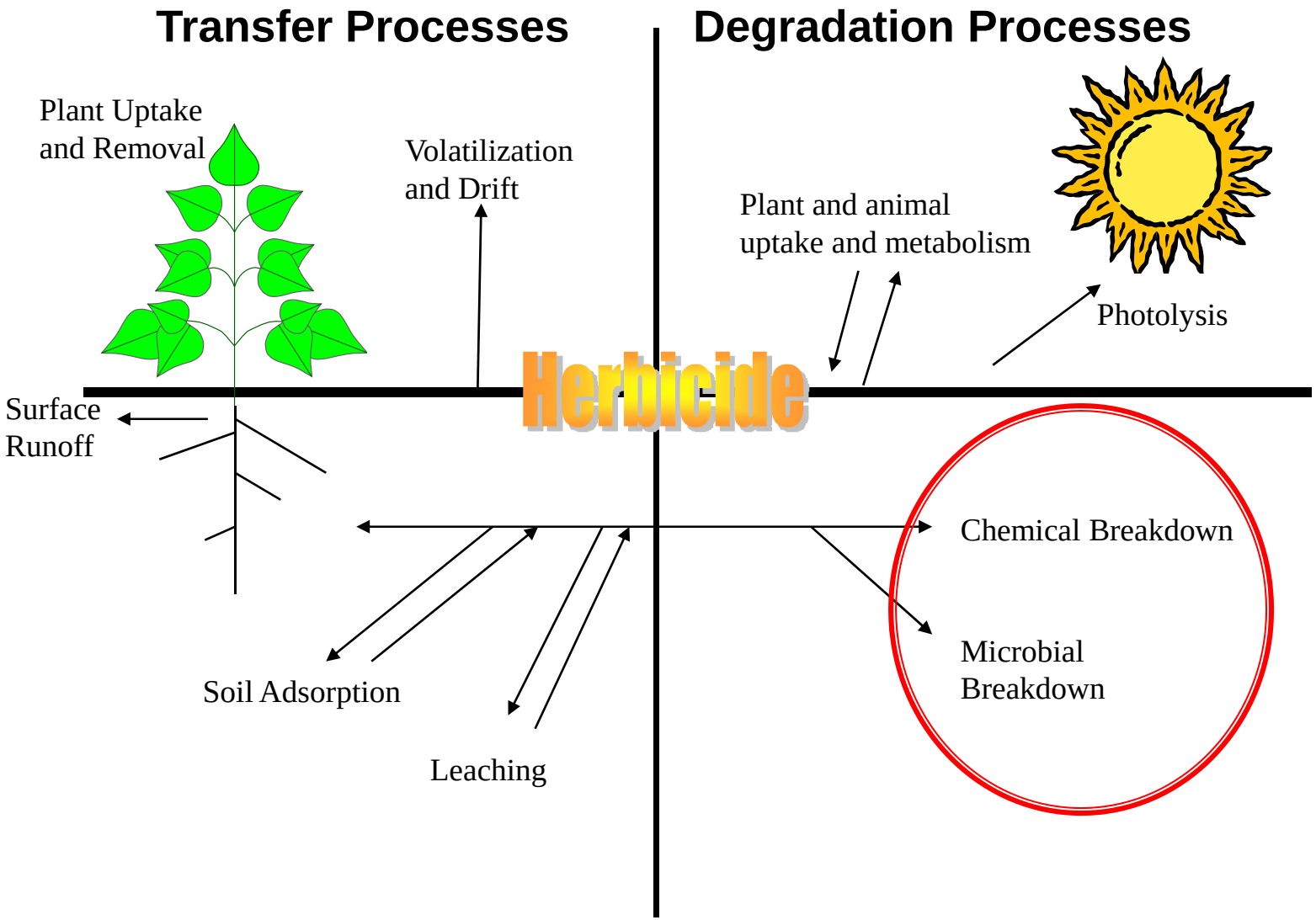
# Herbicide pKa

- Some herbicides are "charged" – weak acids or weak bases
  - At a certain pH (ie it's pKa value) the molecule can shift to the "uncharged" form
    - Acid to neutral, base to neutral, or vice versa
  - Can affect persistence
- Example: prometryn (Caparol)
  - Weak base.  pKa at pH 4.09
    - Relatively stable at neutral pH
    - Slight positive charge at low pH, so more tightly sorbed

# Koc values

- Koc is the ratio of herbicide sorbed to soil vs amount in water in a water/soil slurry (adjusted for organic carbon content of the soil)
  - Low Koc value indicates weak binding
  - High Koc value indicates strong binding
  - Koc examples:
    - 2,4-D ~20 ml g-1
    - Atrazine ~100
    - Pronamide ~800
    - Trifluralin ~7,000
    - Glyphosate ~24,000
    - Paraquat ~1,000,000
      - Antidote for paraquat poisoning = eat dirt

# Herbicide Dissipation



# What (Unusual) Environmental Factors Affect Persistence?

- Unusual (or uneven) moisture
  - Drought
  - Excess moisture
    - Near drippers or micros
    - Pockets of standing water (low spots)
- Unusual soils
  - pH, texture, microbial communities
- Fumigation?
- Micro climate or soil factors

# Causes of Excessive Herbicide Persistence

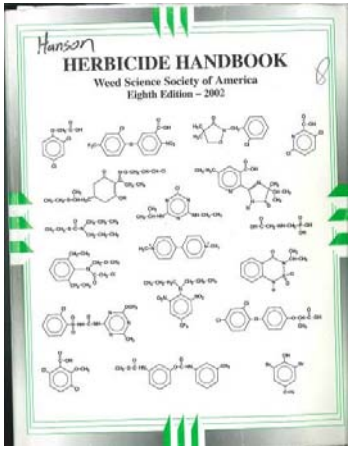
- Herbicide labels are the product of a lot of research to maximize efficacy and minimize crop injury
- Common causes of crop injury include:
  - Over application (miscalc., overlaps)
  - Crop failure and/or early replant
  - Late application timing
  - Adverse weather (esp. drought)
  - Unusual soil conditions (pH, texture)

# Rotational Crop Injury

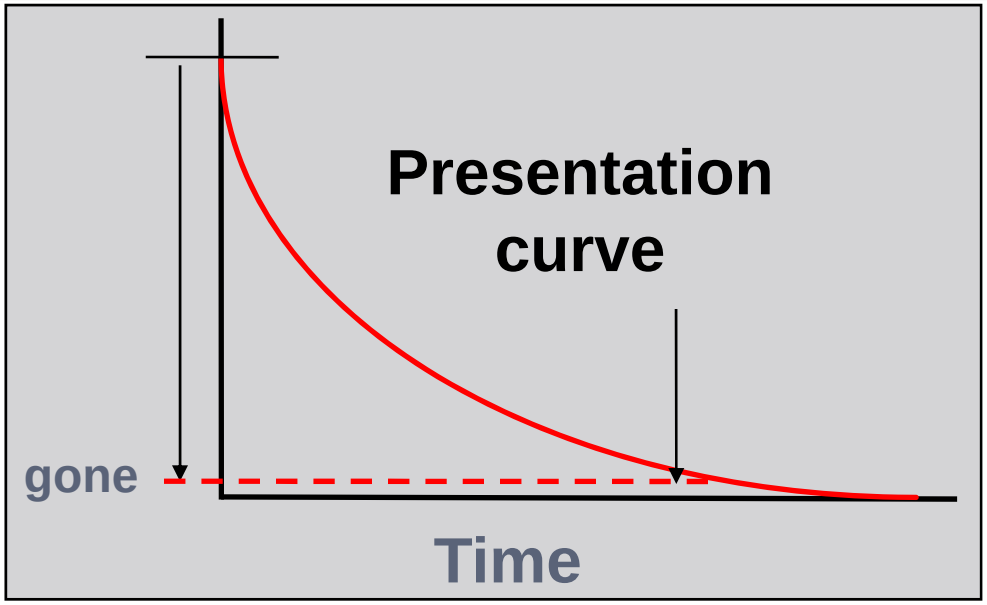
- Some crops are more sensitive than others
  - Read herbicide labels!
    - No restrictions, or very short
    - 30 days
    - 3-6 months
    - 48-60 months!
- Important consideration in some areas
  - Esp. rented or newly purchased land in diverse cropping areas

# Herbicide Persistence Summary

- Herbicides are affected by transfer and degradation processes
- All herbicides are eventually degraded in the soil environment
- Persistence varies considerably depending on chemical properties and environmental factors
  - Microbial and chemical degradation are the most important degradation processes



# Questions?




Brad Hanson
bhanson@ucdavis.edu
530 752 8115
www.ucanr.org/brad.hanson

UC Davis Weed Research and Information Center
http://wric.ucdavis.edu/

UC Davis Statewide Integrated Pest Management Program
http://www.ipm.ucdavis.edu/