What is Environmental Fate?

• Simple definition: what happens to the herbicide after it leaves the sprayer.
Why Does it Matter

• Pesticides are regulated by both EPA and state agencies.

• Environmental profile is a big part of registration at both levels.
Fate of a Herbicide

- Persistence
- Degradation
- Mobility
Herbicide Persistence

• How long a herbicide stays intact in the environment.

• Long Persistence
  – Good for weed control
  – Not good for the environment. The longer it persists, the more likely it is to move off site.
Persistence

- How long do herbicides persist
  - Depends on the properties of the herbicide

<table>
<thead>
<tr>
<th>Herbicide</th>
<th>Half-life (days)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2,4-D</td>
<td>10</td>
</tr>
<tr>
<td>Aminopyralid (Milestone VM)</td>
<td>28</td>
</tr>
<tr>
<td>Picloram (Tordon)</td>
<td>90</td>
</tr>
<tr>
<td>Bromacil (Hyvar, Krovar)</td>
<td>150</td>
</tr>
</tbody>
</table>
Small changes can make big differences

Picloram – half-life 90 days (Tordon)

Aminopyralid – half-life 30 days (Milestone VM)
Dissipation

• The herbicide is broken down and no longer possess herbicidal activity

• Processes include:
  – Microbial – deactivated by soil microbes
  – Hydrolysis – reaction with water
  – Photolysis – deactivated by light
atrazine
Atrazine: Common Metabolites

Atrazine

Hydrolysis

Hydroxyatrazine
What dictates hydrolysis?

• A big factor is pH

• Flumioxazin half-life in water
  – pH 5  3-5 days
  – pH 7  21-24 hours
  – pH 9  14-22 minutes
Atrazine: Common Metabolites

- Atrazine
- Hydroxyatrazine
- De-ethylatrazine
- De-isopropylatrazine

The processes include Microbial degradation and Hydrolysis.
What impacts microbial deg?

- Soil water content.
  - Too little water
    - Herbicide is sorbed to soil and not available.
  - Too much water
    - System becomes anaerobic.
Photolysis

• Herbicide broken down by light
Photolysis

• Herbicide broken down by light

• This is why fluridone (Sonar) will persist longer in muddy water.
Dissipation

• The herbicide is broken down and no longer possess herbicidal activity

• Processes include:
  – Microbial – deactivated by soil microbes
  – Hydrolysis – reaction with water
  – Photolysis – deactivated by light

• Given time, the molecule becomes CO$_2$
Herbicide Mobility - Off-site movement

• If degradation is slow, the more opportunity the herbicide will move off-site
  – Runoff – surface water contamination
  – Leaching – ground water contamination
  – Volatility – non-target injury
Runoff – Lateral Movement
Swath of Death
Lateral movement is bad

Why did this happen? They sprayed an off-label herbicide that is highly persistent and mobile.
Which herbicides are most likely to move?

- Hexaxinone (Velpar) – beware of spraying on back slopes. Some trees are very sensitive.
- Bromacil (Hyvar/Krovar) – can easily move
- Imazapyr – movement is not common, but it is very persistent. A misapplication may cause problems.
Leaching

• Leaching is when a herbicide moves deep into the soil.

• Why would a herbicide leach?
  – Low clay and organic matter content in soil
  – Highly water soluble herbicide
  – Doesn’t bind tightly to soil
  – Long soil persistence
Herbicide adsorption

- herbicide +
- clay
- herbicide -

Organic matter

+ +
- -
Herbicide adsorption

- herbicide
  + herbicide

Sand
Neutral charge
Leaching also depends on the herbicide

Picloram – no charges, hardly binds to clay or organic matter. Persists for a LONG time. Leaching is common.

Can not be used in Florida.

Diquat – strong positive charges, binds tightly to almost anything. Leaching is impossible.

Commonly used in Florida.
Leaching

• Leaching is likely when:
  – herbicide has long soil persistence
  – Herbicide does not bind tightly to soil
    • Soil with high sand - low clay
Volatility

- How likely the herbicide will turn to gas

<table>
<thead>
<tr>
<th>Herbicide</th>
<th>Vapor pressure (mm Hg)</th>
<th>Relative Volatility</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fluridone (Sonar, etc.)</td>
<td>$1 \times 10^{-7}$</td>
<td>Very low</td>
</tr>
<tr>
<td>Glyphosate</td>
<td>$1 \times 10^{-7}$</td>
<td>Very low</td>
</tr>
<tr>
<td>Imazapyr (Habitat, etc)</td>
<td>$2 \times 10^{-7}$</td>
<td>Very low</td>
</tr>
<tr>
<td>Triclopyr amine (Garlon 3A)</td>
<td>$3 \times 10^{-7}$</td>
<td>Very low</td>
</tr>
<tr>
<td>Triclopyr ester (Garlon 4)</td>
<td>$3 \times 10^{-6}$</td>
<td>Low</td>
</tr>
<tr>
<td>2,4-D amine</td>
<td>$8 \times 10^{-6}$</td>
<td>Low</td>
</tr>
<tr>
<td>2,4-D ester</td>
<td>$1 \times 10^{-2}$</td>
<td>Very high</td>
</tr>
<tr>
<td>Dicamba (Veteran)</td>
<td>$9 \times 10^{-6}$</td>
<td>Low</td>
</tr>
</tbody>
</table>
What happens to our common aquatic products?
Glyphosate (Rodeo, others)

- **Persistence**: binds to soil immediately and is not available to plants.
- **Mobility**: non-mobile
- **Accumulation**: none. Glyphosate is readily excreted by animals.
- **Degradation**:
  - Photolysis – none
  - Volatility – none
  - Microbial – 20 days (but not available in soil)
Imazapyr (Arsenal, Habitat)

- **Persistence**: Relatively long persistence in soil (25 to 142 d). Not tightly bound to soil.
- **Mobility**: can move through soil. No concerns for groundwater contamination.
  - non-volatile
- **Accumulation**: none. It is readily excreted by animals.
- **Degradation**:
  - Soil: microbes (25-150 days)
  - Water: light (2-3 day half-life)
Triclopyr (Renovate, Garlon)

- **Persistence**: Relatively short persistence in soil (30 d). Not available for uptake by plants.
- **Mobility**: Leaching or runoff is not a concern.
  - Relatively non-volatile
- **Accumulation**: None. It is readily excreted by animals.
- **Degradation**:
  - Soil: microbes
  - Water: light, half-life of 4 hours in water.
Fluridone (Sonar)

- **Persistence**: Half-life is about 20 days
- **Mobility**: N/A
- **Accumulation**: none. It is readily excreted by animals.
- **Degradation**:
  - Light – will persist longer in muddy water.
Flumioxazin (Valor)

- **Persistence**: In water, days to minutes.
- **Mobility**: non-volatile
- **Accumulation**: none. It is readily excreted by animals.
- **Degradation**:  
  - **Water**: pH dependant chemical hydrolysis  
    - pH 5 – 3 to 5 days  
    - pH 7 – 1 day  
    - pH 9 – 15 minutes
Conclusion

- Herbicide fate
  - persist,
  - move off site, or
  - degrade in the environment.
Conclusions

• Degradation of a herbicide in the environment occurs by microbes, light, or chemical reactions in the water.
• Most of the herbicides we use today have a relatively short life in the environment.
• If they are found to persist too long, they will not be granted registration by EPA.