Environmental Fate of Forestry Herbicides

Vickie Tatum
NCASI
October 25, 2016
Environmental Fate

- Where does it go?
- How does it get there?
- What happens when it gets there?
Where does it go?

- Offsite
- Onsite
How does it get offsite?

- Spray Drift
- Runoff
Minimizing Spray Drift

- Use of modern spray drift reduction technologies significantly reduces pesticide drift

- NCASI herbicide use survey asked about use of spray drift reduction techniques
Drift reduction techniques used in forestry

- Use of extremely coarse, very coarse, or coarse spray droplets
- Flow control devices
- Boom/rotor ratios <75%
- Low application heights
- Meteorological limits
- On-board GPS
- Aircraft velocity limits
- Half-boom spraying near streams
- Drift reduction adjuvants
- Straight/level flight paths to reduce shearing
- Parallel flight path near sensitive areas
- Spray buffers
Spray Buffers

- Riparian vegetative buffers effectively mitigate off-site movement via spray drift
    - With OFPA-specified buffers, average reduction in stream deposition was 92% with very fine to fine droplets (chosen to maximize drift potential)
- Key component of forestry best management practices (BMPs)
Runoff

- Modern forestry BMPs are highly effective at preventing runoff of herbicides into adjoining water bodies
  - Louch et al. Potential risks to freshwater aquatic organisms following a silvicultural application of herbicides in Oregon’s coast range. Integrated Environmental Assessment and Management. DOI:10.1002/ieam.1781.

- Implementation rates of forestry BMPs are high
If herbicides do get into water, what can happen to them?

- Diluted and removed by flowing water
- Partition into sediments
- Adsorb to suspended sediment
- Remain dissolved in water
- Volatilize
- Degrade

A lot of this, at first

Then, mostly this
Onsite – Where does it go?

Herbicide Spray

Interception
By vegetation

Falls on soil
Most is intercepted by vegetation

Aerial applications of glyphosate and triclopyr 3-8 yrs post-harvest/replanting of spruce in Ontario aspen-spruce-mixedwood forest

Mean Deposit (% of nominal rate)

Aspen canopy foliage

Sampling Height (meters above ground level)

Shrub

Ground-cover

Fate of Glyphosate in Vegetation

- 3 study sites (Oregon, Michigan, Georgia)
- Aerial application (helicopter) of 4.12 kg (a.e.)/ha of glyphosate, no surfactant
- Residues on vegetation sampled at 8 stations/site

Glyphosate in Upper Foliage

Days Post-Application

Glyphosate % Remaining

Initial 1 3 7 14 28-30 56-63 120-122 180-187 321-346 398-409

“Missing” data points = no foliage due to defoliation or winter leaf fall

Oregon
Michigan
Georgia
Glyphosate in Surface Litter

Days Post-Treatment

Glyphosate % Remaining

Oregon
Michigan
Georgia

*Oregon data truncated for scale
Once herbicides get on/in soil, what can happen to them?

- Adsorb to soil or components of plants
- Be absorbed by plants
- Remain dissolved in soil water
- Volatilize
- Leach
- Degrade

Mostly this
Fate in Soil

Volatilization

Soil Surface

Dissolved Herbicide

Absorption by Plants

Dissolved Herbicide

Adsorption to Plant Roots

Degradation

Leaching

Ground Water

Runoff

Adsorbed to Organic Matter

Adsorbed to Non-Organic Components

Photolysis
Volatilization

- Evaporation of herbicide
  - From the surface of soil or plants
  - Into air spaces within the soil from herbicides dissolved in soil water and subsequently into the atmosphere

- For commonly used forestry herbicides, the tendency to volatilize in the environment is very low

Leaching

- A function of:
  - Herbicide solubility
  - Soil characteristics
  - Post-application rainfall frequency and intensity
  - Tendency to adsorb to soil

- Most forest herbicides are not susceptible to leaching to any great extent under actual field conditions

Adsorption

- It’s a big deal
  - The relative preference of a herbicide molecule for the aqueous and solid phases of a soil will affect every other aspect of its behavior in soil
    - Degradation
    - Leaching
    - Efficacy
    - Overall persistence
  - The soil water is where most of the action (degradation, transport) happens
Degradation

- Non-biological
  - Photolysis
    - Direct – sunlight disrupts chemical bonds
    - Indirect – sunlight generates reactive substances (e.g. hydroxyl radicals) that degrade herbicide molecules
  - Hydrolysis
    - Herbicide molecule reacts with water
  - Oxidation/Reduction
Degradation

- **Biological**
  - **Microorganisms**
    - Most common
    - Microorganisms “digest” herbicide molecules in enzyme-catalyzed reactions
    - Most effective when soil conditions are optimal for microbial activity
  
- **Fungi, plants, invertebrates**
  - May play minor role in some circumstances
All of these factors interact to determine the two indicators that are typically used to describe environmental fate:

- Persistence
- Mobility
Soapbox Moment

- Predictions about persistence and mobility are often made based on indicators of volatility, leaching, adsorption, and degradation that were derived from laboratory studies or in settings that do not resemble forests. There are a multitude of factors present in forests that affect persistence and mobility and are not, or cannot be, adequately replicated in those studies.
Persistence (Half-Life) in Soils in Forestry Field Studies of 4 Most Commonly Used Herbicides

- **Glyphosate**
  - 1-197 days, average 32 days

- **Imazapyr**
  - 35-142 days

- **Metsulfuron Methyl**
  - 7-42 days

- **Sulfometuron Methyl**
  - 12-65 days
Mobility in Soils in Forestry Field Studies of the Four Most Commonly Used Herbicides

- **Glyphosate**
  - Virtually no leaching

- **Imazapyr**
  - Minimal leaching, generally remains in upper 50 cm of soil. No run-off into streams or lateral movement in soil observed in forest dissipation studies in field studies.

- **Metsulfuron Methyl**
  - Generally remains in upper 50 cm of soil, but supporting database not strong

- **Sulfometuron Methyl**
  - Generally remains in upper 8 cm of soil, but supporting database not strong
Fate of Hexazinone at British Columbia Forestry Field Site

Hexazinone Concentration Over Time

- Surface Organic
- Mineral 0-15 cm
- Mineral 15-30 cm