Interaction of pesticides with soil

By
Donald Horneck, Ph.D.
Extension Agronomist – HAREC
CCA, CPAg, CPSSc
Outline

- Why the worry
- Factors for movement
  - Soil, pesticide
- Putting the pieces together
Why worry?

Conservation vs. Preservation

- Oceans: 97%
- Ice caps: 2%
- Other: 1%
- Ground water: 1%
- Surface: 0%
Movement depends on

- Soil
- CEC
- Organic matter
- Texture
- Drainage
Movement depends on

✓ Pesticide

✓ Persistance (1/2 life)
✓ Solubility
✓ Partition ($K_{oc}$)
How a pesticide impacts the environment depends on

- Pesticide characteristics
- Additives
- Sunlight
- Soil properties
- Climate
Important soil properties

✓ Drainage
✓ Texture
✓ Organic matter (OM)
✓ Cation exchange capacity (CEC)
✓ Soil pH
✓ Infiltration
“Normal” Quincy soil
Soils make a difference

Quincy Soil
Hydrophobic
This way to Water table

OSU-HAREC
Soils make a difference, once again

Quincy Soil
Hydrophobic
This way to the water table
Atrazine can travel (seep or leach) through soil and can enter ground water which may be used as drinking water. Atrazine has been found in ground water. Users are advised not to apply atrazine to sand and loamy soils where the water table (ground water) is close to the surface and where the soils are permeable, i.e., well drained. Your local agricultural agencies can provide further information on the type of soil in your area and the location of ground water.
12 Best Management Practices for Atrazine

- 1. Incorporate atrazine into the top 2 inches of soil.
- 2. Use fall or early spring applications.
- 3. Use postemergence
- 4. Reduce application rates.
- 5. Split applications.
- 6. Use reduced soil-applied atrazine rates followed by a postemergence herbicide application.
- 7. Use non-atrazine herbicides.
- 8. Use integrated pest management strategies.
- 9. Band herbicides at planting or cultivation.
- 10. Establish vegetative and riparian buffer areas.
- 11. Use proper atrazine rates, mixing, loading, and disposal practices.
- 12. Use conservation practices and structures.
Other complexities

- Irrigation
- Rainfall
- Depth to water table
- Age of water
- Where water goes
Organic Matter

✓ Soil carbon, SOM, OC

✓ The most important variable for affecting sorption

✓ What does OM prevent when a pesticide adsorbs?
Why?

✓ Organic matter has many characteristics
  ✓ High charge (CEC)
    ✓ Cation (+)
    ✓ Also some anion (-)
  ✓ Neutral sorption sites

✓ Partition coefficients
  ✓ Measured as $K_{ocr}$, $K_d$ and $K_{ow}$
What does a partition coefficient tell us?

✓ What is in solution vs. what is in/on soil particles
✓ For example
✓ 1% water vs. 99% soil
✓ Has lots to do with water solubility
Soil makes a difference

Coarse, low organic matter soils are worse case scenario for leaching
Soil water

- Poorly drained soils can:
  - Contaminate groundwater directly when water table is at or near the surface
  - Increase erosion

- Ground water below sandy soils are easily contaminated

- Do we have soils with water near the surface?
Hydrogeology
What does a label insinuate?

- Reduce rate for coarse textured soils
- Increase rate for organic matter
- Do not apply when water is with a specified depth
What does a label insinuate?

- Reduce rate for coarse textured soils
  - Prone to sorption by clay
- Increase rate for organic matter
  - Prone to sorption by OM
- Do not apply when water is within a specified depth
  - Easily leached out
Which one is the dummy?
Glyphosate


OSU-HAREC
Glyphosate cont.

- Mobility/leachability
  - Low
- Runoff potential with soil particles
  - High
- Detection
  - No – but starting to show up

Robert L. Mahler et.al
<table>
<thead>
<tr>
<th>Non-persistent (&lt;30 days)</th>
<th>Moderately persistent (30 to 100 days)</th>
<th>Persistent (&gt;100 days)</th>
</tr>
</thead>
<tbody>
<tr>
<td>alachlor (Lasso)</td>
<td>atrazine (AAtrex)</td>
<td>bromacil (Hyvar)</td>
</tr>
<tr>
<td>aldicarb (Temik)</td>
<td>azinphos-methyl (Guthion)</td>
<td>DBCP (Nemagon)</td>
</tr>
<tr>
<td>butylate (Sutan)</td>
<td>carbaryl (Sevin)</td>
<td>dieldrin (Alvit)</td>
</tr>
<tr>
<td>captan</td>
<td>carbofuran (Furadan)</td>
<td>diuron (Karmex)</td>
</tr>
<tr>
<td>dalapon</td>
<td>chlorpyrifos</td>
<td>lindane</td>
</tr>
<tr>
<td>dicamba (Banvel)</td>
<td>chlorsulfuron (Glean)</td>
<td>paraquat</td>
</tr>
<tr>
<td>dimethoate (Cygion)</td>
<td>DCPA (Dacthal)</td>
<td>picloram (Tordon)</td>
</tr>
<tr>
<td>methomyl</td>
<td>glyphosate (Roundup)</td>
<td></td>
</tr>
<tr>
<td>methyl parathion</td>
<td>linuron</td>
<td></td>
</tr>
<tr>
<td>oxamyl (Vydate-L)</td>
<td>metribuzin (Sencor)</td>
<td></td>
</tr>
<tr>
<td>2,4-D</td>
<td>oxyfluorfen (Goal)</td>
<td></td>
</tr>
</tbody>
</table>

Robert L. Mahler et al.
Table 3. Factors that increase the probability of contamination of groundwater by pesticides.

<table>
<thead>
<tr>
<th>Pesticide factors</th>
<th>Soil properties</th>
<th>Site conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Long persistence (long half-life)</td>
<td>Sandy or gravelly soil (high permeability)</td>
<td>Shallow groundwater (less than 25 feet)</td>
</tr>
<tr>
<td>High mobility (high leaching hazard)</td>
<td>Low organic matter content (less than 2%)</td>
<td>Excessive irrigation</td>
</tr>
<tr>
<td>High application rate</td>
<td></td>
<td>Heavy rainfall</td>
</tr>
<tr>
<td>Chemigation</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Robert L. Mahler et al.

OSU-HAREC
So be careful!
Questions?

Be more careful than this!
Impact on water
Water movement

- Wetting Front
- Finger Flow Through Macropores
- Water Table
ET vs. precipitation/irrigation

![Graph showing potential evapotranspiration and average precipitation over the months of the year. The graph indicates a peak in potential evapotranspiration in July and August, while average precipitation is lower and more consistent throughout the year.](image-url)
Impact on water
Water movement
This way to the water table
<table>
<thead>
<tr>
<th>Chemical</th>
<th>Concentration</th>
<th>Toxicity</th>
<th>Solubility</th>
<th>pH</th>
<th>LOEC</th>
<th>NOEC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Malathion</td>
<td>1,800</td>
<td>0.0</td>
<td>extremely low</td>
<td>130</td>
<td>80</td>
<td></td>
</tr>
<tr>
<td>1,3-Dichloro-</td>
<td>10</td>
<td>32</td>
<td>moderate</td>
<td>2,250</td>
<td>290 billion</td>
<td></td>
</tr>
<tr>
<td>propene</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dicamba</td>
<td>14</td>
<td>2</td>
<td>very high</td>
<td>400,000</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Benomyl</td>
<td>67</td>
<td>1,900</td>
<td>low</td>
<td>2</td>
<td>0.001</td>
<td></td>
</tr>
<tr>
<td>Diuron</td>
<td>90</td>
<td>480</td>
<td>moderate</td>
<td>42</td>
<td>0.69</td>
<td></td>
</tr>
<tr>
<td>Bensulide</td>
<td>120</td>
<td>1,000</td>
<td>moderate</td>
<td>5.6</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>Prometon1</td>
<td>500</td>
<td>150</td>
<td>very high</td>
<td>720</td>
<td>77.3</td>
<td></td>
</tr>
</tbody>
</table>

OSU-HAREC
Pesticide
Half-life
Koc
GUS
Movement rating
Solubility
Vapor pressure

- Umatilla 4,294,000
- Mid Willamette 2,875,002
- Malheur 1,690,108
- Hood 1,115,653
- Klamath 913,274
- Low Willamette 905,826
- Deschutes 481,873
- Rogue 337,053
- Upper Willamette 243,768
<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Atrazine</strong></td>
<td>2</td>
<td>0.018</td>
</tr>
<tr>
<td><strong>Atrazine-desethyl</strong> (atrazine metabolite)</td>
<td>9</td>
<td>0.022</td>
</tr>
<tr>
<td><strong>Chlorpyrifos</strong></td>
<td>2</td>
<td>0.007</td>
</tr>
<tr>
<td><strong>DCPA (Dacthal)</strong></td>
<td>4</td>
<td>2.458</td>
</tr>
<tr>
<td><strong>Simazine</strong></td>
<td>5</td>
<td>0.044</td>
</tr>
<tr>
<td><strong>Terbacil</strong></td>
<td>2</td>
<td>0.016</td>
</tr>
</tbody>
</table>
The Nitrogen Cycle
Why we worry about nitrates

✓ Poor fertilizer use
  ✓ Expensive
✓ Health concerns
  ✓ 10 ppm NO$_3$-N standard
✓ Indication of a link between the surface and ground water - i.e. what else may be moving?
Fertilizer example

✓ Anhydrous
✓ Ever smell ammonia behind applicator?
  ✓ Moisture
  ✓ Seal
  ✓ Texture

OSU-HAREC
Nitrogen source

Yield of Total Nitrogen from Major Watersheds (1996-1999)

Total Nitrogen (pounds of nitrogen per sq. mile per year)
- Data Not Available
- Less than 10
- 10-600
- 600-1,500
- 1,500-3,000
- 3,000-10,000

Figure 2. Increases in amount of fertilizer sold and number of water rights issued with time reflect the increase in irrigated farming in Stafford County, Kansas.
N-cycle (cont.)

Nitrate $\text{NO}_3^-$

Ammonium $\text{NH}_4^+$

Plant Uptake

Nitrification

Organic Nitrogen
Nitrates

What characteristics make nitrate mobile?
Nitrate

- Negatively charged
- Very water soluble
  - Calcium nitrate
  - Ammonium nitrate
Nitrate load

![Graph showing Nitrate Load Carried by Major Rivers](image)

How it happens

✓ Soil dependant
✓ Crop specific
  ✓ Rooting
    ✓ Onions vs grasses
✓ Uptake characteristics
  ✓ Potatoes vs onions
Drip irrigation – under drip line

Available water, mm

Date


OSU-HAREC
Drip irrigation - between beds

available water, mm

date

OSU-HAREC
How to avoid

✓ Match crop demand
  ✓ Water
    ✓ Be careful early and late
  ✓ N
✓ Cover crops
Cover crops

![Graph showing nitrate concentrations in soil with and without cover crops.](image)

Figure 3. Effect of a cereal rye cover crop on soil nitrate concentrations (ppm) in broccoli plots fertilized the previous spring with 250 pounds N/acre. Samples were taken April 15, 1992. (Data from Hampi and Hart, 1993.)

Using winter cover crops to reduce nitrate contamination of ground water requires the establishment of the crop early enough in the fall to have adequate growth during the fall and winter rains. Relay interplanting of the cover crop into the standing cash crop during the summer has shown promise in getting a crop well established by winter. Selection of fast-growing cultivars is also important.
Timing

Sandy Loam Soil Receiving 30 Tons Manure/Acre

Nitrate Concentrations (ppm)

Pre-Manure
Mid-Season
Harvest

Root Zone

Depth (m)
Questions?
Wood Ash

✓ Mostly from wood-fired electric plants
  ✓ combustion not as complete as in wood stoves
  ✓ substantial carbon (charcoal) content

✓ A very good source of lime and potassium
  ✓ also supplies Ca, some P and Mg

✓ Water added to quench and to aid handling
Wood Ash Content

- 20 to 40 % moisture content

- Lime equivalence = 35-50 % dry (~35% as spread)

- Available $P_2O_5 = 0.6-1.0$ % dry (~0.6 % as spread)

- Soluble $K_2O = 1.5-3.0$ % dry (~1.6 % as spread)

- Application rate determined by lime, P, or K content
Caustic Biosolids
Caustic Biosolids

✓ Wastewater sludge or septage treated with caustic lime/high heat (N-Viro™ process)
  ✓ 1/3 each biosolids/ash/kiln dust
  ✓ “class A” residual (no site/crop restrictions)

✓ Supplies lime, N, P, and K
  ➢ much of original N content lost as free ammonia
  ➢ contains hydrated lime – caustic to living plants

✓ Primarily calcitic lime
  ➢ can cause Mg deficiency if overapplied

OSU-HAREC
Other Waste Materials

- Treatment plant sludge/biosolids
  - Lime-stabilized class B residual
  - Requires site license
  - 38 month holdout for potato production

- Poultry manure
  - 1 to 3% lime equivalence in layer manure
  - High transportation price
  - Not neighbor friendly
Summary
Alternative Liming Materials

✓ Inexpensive and beneficial
  ➢ If used at proper rates, where needed

✓ Not a complete substitute for standard lime
  ➢ Excess use may induce deficiencies (Mg, K)
Summary

Alternative Liming Materials

- Variable nutrient content/lime value
- Variable moisture content
- Handling difficulties if stockpiled too long
Acknowledgements

Thanks to

*New England Organics*

and

*Soil Preparation Inc*

for example materials

OSU-HAREC
Calculating Application Rate: an example

Soil test recommendation:
Lime requirement = 2000 lb/A CaCO₃ to raise soil pH to 6.0

Lime mud analysis:
CCE = 75 % (dry basis)
Total (dry) Solids = 60 % (40 % water)

Calculate application rate of material as spread
2000 lb CaCO₃ / 0.75 (% CCE dry) = 2670 lb dry material/acre

2670 lb dry material / 0.60 (% TS) = 4450 lb wet material/acre
Using winter cover crops requires the establishment of the crop growth during the fall and winter months. The standing cash crop during the fall and well established by winter. Selection...
Yield of Total Nitrogen from Major Watersheds (1996-1999)

Total Nitrogen (pounds of nitrogen per sq. mile per year)
- Data Not Available
- 10,600
- 600-1,500
- 1,500-3,000
- 3,000-10,000

Wood Ash

• Mostly from wood-fired electric plants
  – combustion not as complete as in wood stoves
  – substantial carbon (charcoal) content

• A very good source of lime and potassium
  – also supplies Ca, some P and Mg

• Water added to quench and to aid handling
Caustic Biosolids

• Wastewater sludge or septage treated with caustic lime/high heat (N-Viro™ process)
  – 1/3 each biosolids/ash/kiln dust
  – “class A” residual (no site/crop restrictions)

• Supplies lime, N, P, and K
  ➢ much of original N content lost as free ammonia
  ➢ contains hydrated lime – caustic to living plants

• Primarily calcitic lime
  ➢ can cause Mg deficiency if overapplied
Calculating Application Rate: an example

Soil test recommendation:
Lime requirement = 2000 lb/A CaCO$_3$ to raise soil pH to 6.0

Lime mud analysis:
CCE = 75 % (dry basis)
Total (dry) Solids = 60 % (40 % water)

Calculate application rate of material as spread
2000 lb CaCO$_3$ / 0.75 (% CCE dry) = 2670 lb dry material/acre

2670 lb dry material / 0.60 (% TS) = 4450 lb wet material/acre