Water: The Smallest Factor That Makes the Greatest Difference

Fred Fishel
UF/IFAS Agronomy/Pesticide Information Office
Water

- Water often comprises 95 to greater than 99 percent of the spray solution

- Water quality parameters affect herbicide performance:
  - pH
  - Dissolved minerals
  - Suspended solids
  - Temperature

- Poor water quality
  - Reduce solubility
  - Decrease absorption
  - Decrease half-life of active ingredient
Herbicide Degradation

Mix up a load and spray till it’s gone, right?
Herbicide Degradation

• Pesticides start to break down when they are in water
  – Water (hydrolysis)
  – Light (photodegradation)
  – Microbes

• These processes can be fast or slow. It depends...
Water pH

• **Indicator of alkalinity or acidity**
  
  – Scale from 0 to 14
  
  – Logarithmic concentration scale of:
    
    • If \( H^+ = OH^- \) : then pH is 7.0 or neutral
    
    • If \( H^+ > OH^- \) : then pH is acidic
    
    • If \( H^+ < OH^- \) : then pH is alkaline (basic)
## Water pH

<table>
<thead>
<tr>
<th>pH Value</th>
<th>Substance</th>
</tr>
</thead>
<tbody>
<tr>
<td>14.0</td>
<td>sodium hydroxide</td>
</tr>
<tr>
<td>12.6</td>
<td>bleach</td>
</tr>
<tr>
<td>11.5</td>
<td>ammonia</td>
</tr>
<tr>
<td>10.2</td>
<td>milk of magnesia</td>
</tr>
<tr>
<td>9.3</td>
<td>borax</td>
</tr>
<tr>
<td>8.4</td>
<td>baking soda</td>
</tr>
<tr>
<td>8.0</td>
<td>sea water</td>
</tr>
<tr>
<td>7.4</td>
<td>human blood</td>
</tr>
<tr>
<td>7.0</td>
<td>distilled water</td>
</tr>
<tr>
<td>6.8</td>
<td>tea</td>
</tr>
<tr>
<td>6.7</td>
<td>milk</td>
</tr>
<tr>
<td>6.0</td>
<td>atmospheric water</td>
</tr>
<tr>
<td>5.0</td>
<td>pickle juice</td>
</tr>
<tr>
<td>4.5</td>
<td>tomatoes</td>
</tr>
<tr>
<td>4.2</td>
<td>orange juice</td>
</tr>
<tr>
<td>4.0</td>
<td>wine and beer</td>
</tr>
<tr>
<td>2.8</td>
<td>vinegar</td>
</tr>
<tr>
<td>2.2</td>
<td>lemon juice</td>
</tr>
<tr>
<td>2.0</td>
<td>stomach acid</td>
</tr>
<tr>
<td>1.0</td>
<td>battery acid</td>
</tr>
<tr>
<td>0.0</td>
<td>hydrochloric acid</td>
</tr>
</tbody>
</table>
Water pH

• Scale is logarithmic; so:
  – pH 5.0 is 10x more acidic than pH 6.0
  – pH 4.0 is 100x more acidic than pH 6.0
Water pH

• Some pesticides lose effectiveness when mixed with alkaline water
• pH of 8 to 9 can greatly diminish or cause complete loss of effectiveness
• Most common with some insecticides:
  – Carbamates and organophosphates
• Few fungicides and herbicides susceptible
Water pH

• “General rule:”
  – Herbicides, insecticides, and fungicides perform best in slightly acidic water, pH 4 - 6.5
Water pH

• Most water sources in FL derive from limestone aquifers
• Contain high levels of carbonates – removes $\text{H}^+$ from water, thus increases pH
## Water pH

<table>
<thead>
<tr>
<th>Pesticide</th>
<th>pH 6</th>
<th>pH 7</th>
<th>pH 8</th>
<th>pH 9</th>
</tr>
</thead>
<tbody>
<tr>
<td>flumioxazin</td>
<td>---</td>
<td>24 h</td>
<td>---</td>
<td>15 min</td>
</tr>
<tr>
<td>captan</td>
<td>---</td>
<td>8 h</td>
<td>10 min</td>
<td>2 min</td>
</tr>
<tr>
<td>carbaryl</td>
<td>125 days</td>
<td>27 days</td>
<td>2-3 days</td>
<td>1-3 days</td>
</tr>
<tr>
<td>dimethoate</td>
<td>12 h</td>
<td>---</td>
<td>---</td>
<td>1 h</td>
</tr>
<tr>
<td>disulfoton</td>
<td>32 h</td>
<td>---</td>
<td>---</td>
<td>7 h</td>
</tr>
<tr>
<td>malathion</td>
<td>8 days</td>
<td>3 days</td>
<td>19 h</td>
<td>---</td>
</tr>
<tr>
<td>phosmet</td>
<td>---</td>
<td>1 day</td>
<td>4 h (pH 8.3)</td>
<td>1 min (pH 10)</td>
</tr>
<tr>
<td>trichlorfon</td>
<td>4 days</td>
<td>6 h</td>
<td>1 h</td>
<td>---</td>
</tr>
</tbody>
</table>
Water pH

<table>
<thead>
<tr>
<th>pH</th>
<th>Half-life (h)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low 6.0-6.2</td>
<td>39.0</td>
</tr>
<tr>
<td>Medium 7.0-7.2</td>
<td>18.6</td>
</tr>
<tr>
<td>High &gt;8.5</td>
<td>1.7</td>
</tr>
</tbody>
</table>

**PRODUCT INFORMATION**

*Clipper* Herbicide is a fast acting contact herbicide that controls selected submersed, emergent and floating aquatic weeds. It is most effective when applied to young, actively growing weeds in water with a pH of less than 8.5.
**APPLICATION AND SPRAYER INFORMATION**

**Mixing Instructions**

- Mix with water having pH of 5 to 7. If pH is higher than 7, use an appropriate buffer to reduce pH to desirable range.
- Fill clean spray tank 1/2 full of desired level with water and add buffering agent if necessary.
- Add the required amount of *Clipper* Herbicide to the spray tank while agitating.
- Fill spray tank to desired level with water. Ensure that *Clipper* Herbicide is thoroughly mixed before making applications. Agitation should continue until spray solution has been applied.
- Mix only the amount of spray solution that can be applied the day of mixing. Apply *Clipper* Herbicide within 12 hours of mixing.
Water pH

How long is too long to hold in the tank?

• “General rules:”
  – A pH between 3.5 and 6 is satisfactory for most spraying and short-term (12–24 hours) storage of most mixtures in a spray tank.
  – A pH between 6 and 7 is adequate for immediate spraying for most pesticides. Do not leave the spray mixture in the tank for more than 1 - 2 hours, to prevent loss of effectiveness.
  – Most products mixed in alkaline water should be sprayed immediately.
Dissolved Minerals

- Water hardness: a measurement of the total amount of calcium and magnesium ions in water
- How hard is hard?
  - There are different sets of standards
    - World Health Organization
    - US Geological Survey
    - UF/IFAS Soil and Water Lab
Dissolved Minerals

UF/IFAS Soil and Water Lab Hardness Scale

<table>
<thead>
<tr>
<th>Interpretation</th>
<th>Hardness (ppm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soft</td>
<td>0 – 17</td>
</tr>
<tr>
<td>Relatively soft</td>
<td>17 – 50</td>
</tr>
<tr>
<td>Moderately hard</td>
<td>50 – 120</td>
</tr>
<tr>
<td>Hard</td>
<td>120 – 170</td>
</tr>
<tr>
<td>Very hard</td>
<td>&gt;170</td>
</tr>
</tbody>
</table>
Dissolved Minerals

• Several herbicides (including 2,4-D, dicamba, and glyphosate) have an overall negative charge
• These herbicides can be influenced by hard water cations
  – Form precipitates
  – Lower probability of passing through plant cuticle
Dissolved Minerals

Glyphosate + Distilled water (Zero hardness)

Glyphosate + hard water
Hard-water Antagonism Study

• Greenhouse study at Michigan State University
• Sunflower used as indicator species
• $^{14}$C-glyphosate absorption measured:
  - Alone
  - + Ca
  - + Ca + AMS
  - Absorption measured at 0, 4, 24, 48 hours following application

# Hard-water Antagonism Study

<table>
<thead>
<tr>
<th>Glyphosate absorption by sunflower after application (h)</th>
<th>0</th>
<th>4</th>
<th>24</th>
<th>48</th>
</tr>
</thead>
<tbody>
<tr>
<td>-------------------------------------------------------</td>
<td>----</td>
<td>----</td>
<td>----</td>
<td>----</td>
</tr>
<tr>
<td>% absorbed</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>---------------------------------------------------------</td>
<td>----</td>
<td>----</td>
<td>----</td>
<td>----</td>
</tr>
<tr>
<td>Glyphosate&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1.4</td>
<td>22.6</td>
<td>20.3</td>
<td>32.5</td>
</tr>
<tr>
<td>Glyphosate + Ca</td>
<td>1.2</td>
<td>4.9</td>
<td>8.0</td>
<td>6.5</td>
</tr>
<tr>
<td>Glyphosate + Ca + AMS</td>
<td>0.8</td>
<td>21.9</td>
<td>28.5</td>
<td>25.3</td>
</tr>
</tbody>
</table>

<sup>a</sup>Isopropylamine formulation

---

Dissolved Minerals

- Increasing Ca concentration decreases glyphosate activity
- Calcium will bind to the negatively charged glyphosate
- Glyphosate + calcium has no herbicidal activity
Ca(NO₃)₂ – Glyphosate Study

- Greenhouse study at University of Tennessee
- Evaluated 4 specified levels (250, 500, 750, 1,000 ppm) of mix-water hardness using Ca(NO₃)₂ with glyphosate
- Visual % control of 4 weed species evaluated
  - Yellow nutsedge
  - Pitted morningglory
  - Broadleaf signalgrass
  - Palmer amaranth

### Ca(NO$_3$)$_2$ – Glyphosate Study

<table>
<thead>
<tr>
<th>Cation</th>
<th>ppm</th>
<th>Y. nutsedge</th>
<th>P. morning glory</th>
<th>B. signalgrass</th>
<th>P. amaranth</th>
</tr>
</thead>
<tbody>
<tr>
<td>None</td>
<td>0 (soft)</td>
<td>76</td>
<td>77</td>
<td>98</td>
<td>99</td>
</tr>
<tr>
<td>Calcium</td>
<td>250 (m. hard)</td>
<td>75</td>
<td>76</td>
<td>98</td>
<td>99</td>
</tr>
<tr>
<td></td>
<td>500 (hard)</td>
<td>64</td>
<td>66</td>
<td>81</td>
<td>89</td>
</tr>
<tr>
<td></td>
<td>750 (hard)</td>
<td>49</td>
<td>56</td>
<td>75</td>
<td>81</td>
</tr>
<tr>
<td></td>
<td>1,000 (e. hard)</td>
<td>40</td>
<td>37</td>
<td>64</td>
<td>78</td>
</tr>
<tr>
<td>LSD</td>
<td></td>
<td>5</td>
<td>6</td>
<td>7</td>
<td>5</td>
</tr>
</tbody>
</table>

Study also compared 3 glyphosate salt formulations: isopropylamine, diammonium, potassium: no differences

Cations and AMS With 2,4-D

- Greenhouse study at Purdue University
- 2,4-D + distilled water and…..
  - + Calcium, Magnesium, Manganese, Zinc
  - Comparisons made with or without addition of AMS
- Visual % control for several weed species…..
  - Horseweed
  - Redroot pigweed
  - Common lambsquarters

# Cations and AMS With 2,4-D

<table>
<thead>
<tr>
<th>Cation solution</th>
<th>Horseweed control (% - visual rating)</th>
<th>Difference (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deonized water + AMS</td>
<td>69</td>
<td>25</td>
</tr>
<tr>
<td>Deonized water</td>
<td>44</td>
<td></td>
</tr>
<tr>
<td>Calcium + AMS</td>
<td>73</td>
<td>48</td>
</tr>
<tr>
<td>Calcium</td>
<td>25</td>
<td></td>
</tr>
<tr>
<td>Magnesium + AMS</td>
<td>68</td>
<td>47</td>
</tr>
<tr>
<td>Magnesium</td>
<td>21</td>
<td></td>
</tr>
<tr>
<td>Manganese + AMS</td>
<td>56</td>
<td>36</td>
</tr>
<tr>
<td>Manganese</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>Zinc + AMS</td>
<td>61</td>
<td>28</td>
</tr>
<tr>
<td>Zinc</td>
<td>33</td>
<td></td>
</tr>
</tbody>
</table>

Dissolved Minerals

- The effects of hard water can be reversed with a water conditioner - commonly ammonium sulfate
- Add the water conditioner to the tank before you add the herbicide

7.4 Ammonium Sulfate

The addition of 1 to 2 percent dry ammonium sulfate by weight or 8.5 to 17 pounds per 100 gallons of water may increase the performance of this product, particularly under hard water conditions, drought conditions or when tank mixed with certain residual herbicides, on annual and perennial weeds. The equivalent rate of ammonium sulfate in a liquid formulation may also be used. Ensure that dry ammonium sulfate is completely dissolved in the spray tank before adding herbicides. Thoroughly rinse the spray system with clean water after use to reduce corrosion.
If you use an additive.....

ADDITIVES
When applying *Clipper* Herbicide to the foliage of floating or emerged aquatic weeds, mix with an adjuvant approved for use in aquatic sites. *Valent* recommends the use of a Chemical Producers and Distributors Association certified adjuvant. Mix *Clipper* Herbicide with a non-ionic surfactant containing at least 80% active ingredient. Follow adjuvant manufacturer’s label rates. Mixing compatibility should be verified by a jar test before using.
Chemical Producers and Distributors of Agrotechnology

- Voluntary adjuvant certification program
- Certified products meet benchmarks set by the American Society for Testing and Materials
- Provides some assurance of product performance

If a product label includes a recommendation for use in aquatic applications, then an aquatic toxicity study is required.
INTACT™

Drift Control & Foliar Retention Agent and Deposition Aid

PRINCIPAL FUNCTIONING AGENTS
Polyethylene glycol, choline chloride, guar gum ........... 43.18%
Constituents Ineffective as Spray Adjuvants ............... 56.82%
TOTAL ........................................................................ 100.00%
All ingredients are approved for use under 40 CFR 180
WA Reg. No. 9349-16001

KEEP OUT OF REACH OF CHILDREN

NON-CROPLAND AND RIGHTS-OF-WAY. NOT FOR AQUATIC USE.

USE RATES
0.5% v/v (4 pints) of Intact per 100 gallons of spray solution.

MIXING
In the absence of specific mixing instructions found on the pesticide label, fill the spray tank with at least 50% of the desired...
Water Testing

http://soilslab.ifas.ufl.edu
Water Testing

• Things to ask the lab concerning your water test:
  – Can you test for pH and hardness?
  – What will be the cost?
  – How much water will you need to run the suite of tests?
  – Do you have guidelines or special containers for collecting and transporting the water samples?
Water Testing

• Forms, boxes, instructions:
  – Local county extension offices

• Collect 1 pint of water in a plastic bottle (no detergent bottles)

http://soilslab.ifas.ufl.edu/
Water Testing

- Total hardness = \((\text{ppm Ca} \times 2.5) + (\text{ppm Mg} \times 4.1)\)
Water Testing

- Litmus paper:
  - Cheap - $5.00/75 tests
  - Can vary by as much as $\pm2.0$ points
Water Testing

- Test strips:
  - Cheap - $6.00/30 tests
  - Can also vary
- More elaborate and expensive instruments are available
Water Testing

- Meters:
  - ExStik
    - ±0.01 accuracy
    - Digital displays
    - Battery-powered
    - $100
Summary

• Pesticide performance can be affected by water chemical and physical quality factors:
  – Suspended solids
  – Dissolved minerals (hardness)
  – Extreme water temperatures
  – pH

• Having your mix water tested is inexpensive compared to the cost of poor pesticide efficacy
Thank You!