Water Quality Impact on Pesticide Performance

A White Paper for Retailers, Custom Applicators, Crop Consultants and Crop Producers
Abstract

Careful consideration is given to many aspects of a pesticide spray application – from nozzle size to weather conditions – but one component that is overlooked time and again is water quality.

This white paper raises awareness of the primary water quality issues that can affect pesticide performance with a special focus on hard water. It also highlights the need for increased water quality testing and identifies solutions to manage issues.

This white paper makes the case that there is an opportunity for growers to maximize their input investment by understanding and properly managing water quality issues that may impede pesticide performance.
INTRODUCTION:
Crop producers, consultants and applicators alike want the same results from a pesticide application – maximum performance that leads to high-yielding crops and healthy returns. Many factors can affect how a pesticide performs, but one that is often overlooked is water quality.

This white paper examines the effect of water quality – hard water in particular – on pesticide performance.

Water: a major factor in spray applications
Most pesticide formulations are created with water as the primary diluent or dispersing medium. In fact, it usually makes up more than 90% of the spray solution.

For the most part, water is viewed as a relatively clean input; there isn’t much thought given to water’s purity if it runs clear. As such, a common misconception is that the quality of water used for pesticide applications is a minor factor in overall efficacy of that application. However, water is an active chemical that can have a negative influence on pesticide performance, due to its:
- Mineral content
- Acidity / alkalinity
- Cleanliness (e.g. organic matter content, silt)

Connecting water quality to product performance
Research clearly shows that the quality of water used for spraying can affect how pesticides perform, including reduced solubility and decreased absorption by the target pest, resulting in inferior performance and the need for re-treatment. Not all pesticides react the same way when mixed with water of compromised quality. Being aware of which ones are prone to antagonism is essential.

Water quality is not immediately connected to reduced product performance. An applicator is more likely to blame other factors for lack of performance (e.g. weather, resistance), or increase the application rate, thereby masking the effect of the water on the product’s performance.

Understanding what is in the water can help determine its quality and whether it is suitable for pesticide application. The key components to consider include: water hardness, turbidity, water pH and bicarbonate.
WATER QUALITY ANALYSIS

To ensure a successful pesticide application, crop producers and applicators must assess the suitability of the water for spraying purposes. This means first understanding what potential issues the water sources may have, then taking the necessary steps to correct the issues of water quality. The best way to do this is through a water quality test.

Collecting chemical and physical information about water can:

- Help optimize pesticide efficacy
- Indicate problems in the water that can be used for guidance in management
- Help track changes over time

Water testing 101

1. **Determine the water source to test.**
   
   If well water is the source, it’s important to note that the water quality may change as the growing season progresses. For instance, as water levels go down, hardness increases. Although the season may have started with 200 or 300 parts per million, by the middle or end, it may be 600 or 700 parts per million, which will have a more drastic effect on herbicide performance. As a result, it is important to test well water two to three times per year.

   Any non-treated water source can change over the course of the season – even dugouts that may be re-charged by ground water. Only municipal-treated water may not change or have very little change.

2. **Determine the testing method.**
   
   Two common options for testing, include:
   
   - Instant tests – simple test strips that are used on-farm to instantly measure pH or water hardness or a combination of both.
   - Lab tests – sending water samples to a certified lab for more thorough analysis.

3. **Determine the right product to use to correct the water quality issues identified through testing.**
   
   Most water quality issues are manageable. Solutions are identified on pages 4 and 5 of this white paper.

   It would be ideal to have water samples tested every time a spray solution is mixed – that not only tells us whether or not we have hard water, but it quantifies the problem so that water conditioner rates can be adjusted. As water hardness increases, so should your rate.

   Chris Stickler
   Director of Technical Services and Product Development
   Loveland Products Inc.

   Test strips give an instant reading of water hardness, allowing the applicator to take corrective action, if necessary.
Reading a water quality report
Below is a typical water quality analysis report; it provides valuable information to anyone preparing a spray solution for optimum performance. Understanding the results is critical for assessing water suitability for herbicide dilution. More details about each factor are described below and on the opposite page.

Spray water quality analysis report

<table>
<thead>
<tr>
<th>Sample Details/Parameters</th>
<th>Result</th>
<th>Qualifier</th>
<th>D.L.</th>
<th>Units</th>
<th>Extracted</th>
<th>Analyzed</th>
<th>Batch</th>
</tr>
</thead>
<tbody>
<tr>
<td>L1195960-8</td>
<td>XYZ Farms</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>R2420961</td>
</tr>
<tr>
<td>Sampled by:</td>
<td>Client</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Matrix:</td>
<td>Water</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Spray Water Suitability</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Bicarbonate (HCO₃)</td>
<td>400</td>
<td>5.0</td>
<td>mg/L</td>
<td>AUG 20</td>
<td>AUG 20</td>
<td></td>
<td>R2421326</td>
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<tr>
<td>Hardness</td>
<td>664</td>
<td>4.8</td>
<td>mg/L</td>
<td>AUG 22</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ICP Cations</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Calcium (Ca)</td>
<td>158</td>
<td>DLA</td>
<td>1.0</td>
<td>mg/L</td>
<td>AUG 21</td>
<td>AUG 21</td>
<td>R2421326</td>
</tr>
<tr>
<td>Potassium (K)</td>
<td>9.6</td>
<td>DLA</td>
<td>1.0</td>
<td>mg/L</td>
<td>AUG 21</td>
<td>AUG 21</td>
<td>R2421326</td>
</tr>
<tr>
<td>Magnesium (Mg)</td>
<td>65.3</td>
<td>DLA</td>
<td>1.0</td>
<td>mg/L</td>
<td>AUG 21</td>
<td>AUG 21</td>
<td>R2421326</td>
</tr>
<tr>
<td>Sodium (Na)</td>
<td>268</td>
<td>DLA</td>
<td>2.0</td>
<td>mg/L</td>
<td>AUG 21</td>
<td>AUG 21</td>
<td>R2421326</td>
</tr>
<tr>
<td>Sulfur (SO₄)</td>
<td>470</td>
<td>DLA</td>
<td>3.0</td>
<td>mg/L</td>
<td>AUG 21</td>
<td>AUG 21</td>
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<tr>
<td>SAR</td>
<td>0.51</td>
<td>0.10</td>
<td>SAR</td>
<td></td>
<td></td>
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<td></td>
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<tr>
<td>pH and Conductivity</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>pH</td>
<td>6.22</td>
<td>0.10</td>
<td>pH</td>
<td>AUG 17</td>
<td>AUG 17</td>
<td></td>
<td>R2419254</td>
</tr>
<tr>
<td>Conductivity (EC)</td>
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<td>10</td>
<td>uS/cm</td>
<td>AUG 17</td>
<td>AUG 17</td>
<td></td>
<td>R2419254</td>
</tr>
<tr>
<td>TDS (Calculated from EC)</td>
<td>832</td>
<td>1.0</td>
<td>mg/L</td>
<td>AUG 17</td>
<td>AUG 17</td>
<td></td>
<td>R2419254</td>
</tr>
</tbody>
</table>

Defining water quality problems and solutions
Water quality issues can be managed when they are identified and quantified. Here are the common issues related to quality and the best solutions that have been identified to date.

**Water Hardness (refer to results for “Hardness” and “ICP Cations”)**
Water hardness is a measure of the total concentration of hard water ions. These include: iron, zinc, magnesium, calcium, sodium and potassium. Calcium (Ca²⁺) and magnesium (Mg²⁺) are the biggest influencers of antagonism because they tend to be found in greater concentrations.

**Effect on pesticide**: Hard water cations react with certain pesticides, especially herbicides, thereby reducing overall pesticide efficacy. Products most affected (but not limited to) are weak-acid herbicides such as glyphosate, glufosinate ammonium and 2,4-D.

**Solution**: Using a water conditioner, such as Choice® Weather Master, combats all the hard water cations that negatively affect weak acid herbicides. (Water conditioners are discussed in greater detail on page 9.)
Hard water is expressed as parts per million (ppm), grains per gallon, or milligrams per litre. (See hard water classification table on page 6.) Measurements of hardness are given in terms of the calcium carbonate equivalent (CaCO₃), which is an expression of the concentration of hardness ions in water in terms of their equivalent value of calcium carbonate. This number represents all hard water cations, but some labs will break this down by individual cation.

**pH (refer to results for “pH and Conductivity”)**

pH is the value that describes the relative acidity or alkalinity of any solution. A neutral pH is 7, greater values are considered “basic” and anything less than 7 is “acidic.”

**Effect on pesticide:** Water pH plays an important role in the stability and efficacy of pesticides. A pesticide can begin degradation or breakdown the moment it is introduced to the spray solution. This process is called alkaline hydrolysis, which is permanent and irreversible. Alkaline hydrolysis, a process that breaks the bonds holding pesticides together, can reduce the life of a pesticide in solution and is significantly affected by water pH. Products most affected are insecticides.

**Solution:** Use a pH reduction agent, such as LI 700®, that will reduce the pH of the spray solution to around 5 which, in most cases, will take care of any disassociation issues. Do not reduce the pH of the spray solution when using sulphonylurea (SU) chemistries. SU technology is more soluble at higher pH. Lowering the pH too much can allow the product to precipitate out of solution and compromise efficacy.

**Turbidity (refer to results for “TDS”)**

Water turbidity is a measure of the Total Suspended Solids (TSS) as opposed to Total Dissolved Solids (TDS), often associated with various salts.

**Effect on pesticide:** Turbidity can reduce the effectiveness of pesticides. If TDS is below 250, there is less chance that pesticide performance will be affected. Three main herbicides affected by turbidity (suspended solids including soil particles and organic matter) are glyphosate, diquat (Reglone®) and Paraquat (Gramoxone®).

**Solution:** Water should be clean and clear of suspended solids for all pesticide applications. Using a water conditioner such as Choice Weather Master will help reduce the negative affects that the TDS may have on the pesticide’s performance.

**Bicarbonate (refer to results for “Bicarbonate”)**

Bicarbonates contain the anion HCO₃ (negative charge) that is always associated with positively charged cations such as sodium and calcium. This contributes to the alkalinity of a water sample.

**Effect on pesticide:** There is reduction of herbicide uptake at bicarbonate levels above 500 ppm with some pesticides, especially those in the “dim” groups such as sethoxydim (Poast® Ultra), cethodim (Centurion®/Select®) and tralkoxydim (Achieve®) as well as 2,4-D.

**Solution:** One recommendation to overcome the antagonistic effect of bicarbonate in spray mixing water is to add ammonium sulphate at 1% v/v to improve uptake.
FOCUS ON HARD WATER

As discussed earlier in this paper, hard water contains minerals (cations) such as calcium, magnesium and iron. The greater the concentration of these minerals, the harder the water.

As in magnets, opposite charges attract: negatively charged pesticide molecules attach to the positively charged iron, calcium, and magnesium cations in hard water. The binding of pesticides with these cations creates molecules that:

- Cannot enter the target pest
- Enter at a much slower rate
- Precipitate out of the solution

The more the pesticide is bound to minerals, the more “diluted” the product becomes in the tank. In some cases, the chemically altered molecule may be unable to dissolve in water, penetrate the leaf tissue, attach to the site of activity in the pest to disrupt biological functions, or perform as a pesticide. These effects are not limited to the spray tank environment but extend to the spray solution on the leaf surface, which can affect product uptake.

"Cations are positively charged ions that make water hard. Because they’re positively charged and many herbicides carry a negative charge, they tend to tie up the herbicide by forming complexes that aren’t readily taken up by the target. So, in order for us to have more active herbicide, we need to do something to handle those hard water cations."

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Director of Technical Services and Product Development
Loveland Products Inc.

Classifying water hardness

Most accepted classifications of hard water are based on the U.S. Geological Survey. Water that measures more than 60 ppm has some degree of hardness.

<table>
<thead>
<tr>
<th>Parts per million (ppm)</th>
<th>Grains per gallon (gpg)</th>
<th>Classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;60</td>
<td>&lt;3.5</td>
<td>Soft</td>
</tr>
<tr>
<td>60 - 120</td>
<td>3.5 - 7.0</td>
<td>Moderately Hard</td>
</tr>
<tr>
<td>120 - 180</td>
<td>7.0 - 10.5</td>
<td>Hard</td>
</tr>
<tr>
<td>&gt;180</td>
<td>&gt;10.5</td>
<td>Extremely Hard</td>
</tr>
</tbody>
</table>
Prevalence of hard water

Hard water is found throughout Canada. As clearly depicted in the map, the degree of hardness varies by region. The prairie provinces contend with the hardest water in the country. The majority of producers and applicators throughout North America do not test their water source very often – if at all – and are not aware of the impact hard water may have on pesticide performance.

Effect on weak-acid herbicides

Every spray tank containing crop protection chemicals can be impacted by the presence of hard water. Glyphosate, glufosinate ammonium (Liberty®) and other weak-acid products are especially compromised. Hard water ties up these chemistries due to their slightly negative charge.

WEAK-ACID HERBICIDES

Weak acid is a chemical compound that does not ionize or dissociate readily in an acidic solution. Here is a partial list of some key weak-acid herbicides currently used in Canada:

- 2,4-D Amine
- Amitrole
- Atrazine
- Bentazon
- Clethodim
- Clopyralid
- Dicamba
- Endothal
- Fluazifop
- Glufosinate Ammonium
- Glyphosate Isopropylamine
- Glyphosate Potassium
- Imazamox
- Imazapyr
- Imazethapyr
- MCPA Amine
- Metsulfuron-Methyl
- Paraquat
- Picloram
- Quizalofop
- Sethoxydim
- Tralkoxydim
Maximizing glyphosate performance

Glyphosate molecules that bind to cations present in hard water have reduced absorption into plants, reducing weed control. As a result, additional glyphosate would be needed to compensate.

Here is an example:
Water hardness is 664 ppm expressed as CaCO₃, glyphosate applied at 0.5 Litre per acre at 10 gallons per acre (GPA) total volume.

\[
\text{GPA} \times \text{hardness in ppm} \times 0.00047 = \text{percent glyphosate complexed}
\]

\[
\frac{10 \times 664 \times 0.00047}{0.1321} = 23.62\% \text{ of glyphosate complexed}
\]

To compensate for the complexing of glyphosate molecules by hard water ions, 23.6% more herbicide (i.e. an additional 120 mL/ac) would have to be used.* (Based on a 360 gai formulation.)

Rather than increasing the rate of the herbicide, water conditioners, such as Choice Weather Master, counteract the effects of hard water on glyphosate. Multiple sequestering and chelating agents in Choice Weather Master bind to all hard water cations and prevent them from combining with negatively charged herbicides. (This process is further described on page 9).

**SPRAY WATER SUITABILITY GUIDELINES**

<table>
<thead>
<tr>
<th>Herbicide</th>
<th>Maximum Water Hardness (ppm CaCO₃ equivalent)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Glyphosate use rate</td>
<td></td>
</tr>
<tr>
<td>Low rates for annual grass weeds</td>
<td>350</td>
</tr>
<tr>
<td>Higher rates for perennial weeds</td>
<td>700</td>
</tr>
<tr>
<td>2,4-D amine</td>
<td>&lt; 600</td>
</tr>
</tbody>
</table>

Information is based on a 360 gai formulation of glyphosate

Application at 20 GPA. Hardness 2500 ppm as CaCO₃
(There were no differences in the response from 200 to 8000 ppm.)

Photo courtesy: DuPont

*Always read and follow label directions.
For someone whose glyphosate application did not perform, they might assume they’re dealing with a resistant or highly tolerant weed population. They might say: ‘Well, it didn’t work this time. I obviously didn’t use enough glyphosate.’ But if they’re dealing with hard water, an increase in the glyphosate rate may not solve the problem.

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MANAGING WATER SPRAY QUALITY
Enhancing performance with adjuvants
An adjuvant is a substance intended to improve activity or application of a pesticide. The pesticide label may or may not specify use of an adjuvant, but it is widely known that adjuvants can help a product perform better.

All adjuvants are not the same – one class of adjuvant is water conditioners. The purpose of conditioning water is to maximize the effectiveness of the pesticide. Broadly defined, water conditioners are added to the spray solution or tank-mix to eliminate problems associated with water hardness.

There are two key benefits of conditioners:
- They tie up all mineral cations that can impede pesticide performance
- They lower the risk of pesticide failure and the added costs when it happens

Water conditioning strategies for hard water
There are three ways that the industry uses water conditioners to manage the issue of hard water.

1. Removal of antagonistic ions by “competitive salting” to insoluble or very slightly soluble forms.
   The most commonly used water conditioner is ammonium sulfate (AMS). Once AMS is put into the tank, some disassociation occurs. The ammonium and sulfate both break off and the sulfate portion attaches to hard water cations to form “salt.” Experience shows that AMS is most effective with calcium as it is fairly insoluble – the other compounds are more soluble and go back into solution, freeing up the cations again.

2. “Pre-attachment” of a preferred cation to the herbicide (i.e. one that doesn’t antagonize absorption). This effectively “blocks” attachment by antagonistic cations.
   Ammonium ion sources, for example, offer the pre-attachment capacity to herbicides.

3. Removal from antagonistic availability by “sequestering, chelating or complexing.”
   This strategy relies upon structures to hold cations very securely and prevent attachment to herbicides. This action makes the cation unavailable to antagonize glyphosate or other weak-acid herbicides.
Unique “Choice”
Choice Weather Master is a unique water conditioning agent. It is designed for hard water conditions by locking up hard water cations to maximize herbicide performance. It sequesters all cations found in water – not just calcium – to deliver impressive results (see graph on page 14). It is unique because it uses all three strategies listed above. Here are some other features:
- Easy-to-use liquid formulation
- Concentrated formulation means less product required to do the job and less handling
- Compatible with all forms of glyphosate
- Should be used where hard water exists and applying weak-acid herbicides (glufosinate ammonium, Clopyralid, etc.)

When it comes to water conditioning, we need to have technology that can handle the hard water cations indiscriminately. It doesn’t matter if it’s calcium, magnesium, potassium or sodium – as long as it’s got a positive charge we need to use technologies that will handle anything with a positive charge. There are three different ways you can handle that: sequestering, chelating or complexing. In Choice, we use a combination of sequestrants and complexing agents to handle hard water cations. It normally works best if you add it to the tank first so we can sequester or complex the hard water cations before the introduction of the herbicide to the tank mix.

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**Management strategies for hard water**

In order to manage hard water in spray solutions, knowledge is power:

- Know the level of water hardness
- Know the types of cations present and their respective concentrations
- Know what herbicides are susceptible to hard water antagonism (e.g. glyphosate and glufosinate ammonium)
- Know the water source (e.g. ground or surface)

When these parameters are known, it is easiest to solve the issue of hard water in a spray solution. Of course, it is not always possible to know the details of all these elements.

Here are some specific hard water solutions:

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hard water level is unknown</td>
<td>Apply Choice WM at a rate of 4 L/1,000 L</td>
</tr>
<tr>
<td>Hard water level and composition is known</td>
<td>Rate of Choice WM to be applied is based on water hardness value. For every 100 ppm of hardness, the rate of Choice WM is 0.1% up to 0.5%. If mainly calcium, apply Choice WM at 2.5-5 L per 1,000 L or ammonium sulphate (AMS) at 10-20 L per 1,000 L depending on water hardness value. If magnesium or iron are present in higher amounts, apply Choice WM at 2.5-5 L per 1,000 L</td>
</tr>
<tr>
<td>Hard water level is very high but has high levels of magnesium and/or iron</td>
<td>Apply 20 L of AMS + 1.5 L Choice WM per 1,000 L or find another water source</td>
</tr>
</tbody>
</table>
Improving weed control of glyphosate using Choice Weather Master water conditioner in hard water

This graph shows that glyphosate activity will be reduced in the presence of hard water. Adding more glyphosate can also overcome the hard water antagonism by using some of the glyphosate to tie up the hard water and leave the rest to do its job. As this is an inefficient use of herbicide, Choice Weather Master plays a role in getting the water herbicide ready regardless of the concentration.

**Formula to compute Choice Weather Master dose**

Hardness (expressed as CaCO₃ in ppm) x 1 = Number of mL per 100 L

<table>
<thead>
<tr>
<th>Hardness</th>
<th>Choice Weather Master (mL/100L)</th>
<th>Choice Weather Master (L/1000 L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Up to 300 ppm</td>
<td>300</td>
<td>3</td>
</tr>
<tr>
<td>400 ppm</td>
<td>400</td>
<td>4</td>
</tr>
<tr>
<td>500 ppm</td>
<td>500</td>
<td>5</td>
</tr>
</tbody>
</table>

If we knew exactly how hard the water was, we could dial in that rate. If we don’t know how hard the water is, a half percent across the board is the minimum recommended rate. In some cases, people are only using one-quarter percent, just a quarter per 100 gallon, which is fine if you run into 200 or 300 part per million, but it’s very common to have 400 or 500 parts per million water; that quarter percent just isn’t enough to take care of those hard water cations.

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CONCLUSION

This paper has identified that water quality issues can result in reduced pesticide performance. Even if the sprayer is calibrated and the application is perfect, poor water quality can undermine all other factors. Further, it is proven that poor water quality can be especially problematic for certain families of pesticides – weak-acid herbicides.

This paper also underscores the importance of water quality testing. The quality of the water used in a spray solution should be evaluated and considered just as carefully as the purchase of spray equipment and the selection of pesticide products. A small amount of effort to test water is insurance that the product performs as promised and delivers the expected results.

Looking specifically at Choice Weather Master, the water conditioner is beneficial because it allows crop producers and applicators to better manage pesticide applications and address possible efficacy issues. The easy-to-use and concentrated liquid formation means less product is required to do the job and to be handled. Finally, this paper highlights that a product like Choice Weather Master should be used in any glyphosate or glufosinate ammonium application when hard water is present. The bottom line is that it is a cost-effective management tool to facilitate optimum pesticide performance.
REFERENCES AND SOURCES USED IN THE DEVELOPMENT OF THIS PAPER

Kells, James J., Donald Penner and David Pratt. Substitutes for Ammonium Sulfate as Additives with Glyphosate and Glufonsinate.

North Dakota State University. Understanding a Water Analysis Report.


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