Ortho vs. Poly and Salt Index

Fluid Technology Roundup | December 3, 2015 | Raun Lohry

And Beyond
Everything you need to know
Let’s Be Careful When Defining Salt Index

Original data and definition of salt-index predate many current fertilizers.

Summary: The original data and definition of salt index come from a time before many of the current fertilizer products, especially fluids after the 1940s, were developed. In recent years, some have adopted a method that measures electrical conductivity (EC) and not the original osmotic pressure approach. A few products may have widely different salt index values, depending on methodology used. Salt index, by itself, does not tell us how much of a given product is safe when applied with the seed. It only provides relative differences among products. Many other factors such as soil temperature, soil moisture, and potential free ammonia formation may all impact germination and/or seeding root development.

In the 1940s, dry fertilizer materials available at that time were evaluated for changes that occurred in the soil solution osmotic pressure upon application. In 1943, Rader et al. reported salt index values for 45 dry fertilizer materials based on the osmotic pressure of the soil solution when applied to Norfolk sand. This method involved mixing fertilizer materials with air-dried soil and then spraying with water to bring the moisture content to 75 percent of its moisture equivalent. After five days, the soil solution was removed and evaluated for conductivity and freezing point. The resulting freezing point values were then converted to osmotic pressure by tables developed for vegetable saps. A salt index value was then expressed relative to the increase in osmotic pressure as compared with that obtained with the same weight of sodium nitrate. During this time, three nitrogen (N) containing solutions were evaluated, but they could not be urea-ammonium nitrate solution (UAN) since the N content ranged from 37 to 40.8 percent. A laboratory method was later published by W.L. Jackson in 1958 where salt index of a fertilizer was measured by electrical conductance, rather than by osmotic pressure, relative to sodium nitrate. However, this method generally results in significantly higher salt index readings than the original method and data derived from this laboratory method did not correlate well with earlier soil-applied applications. Fluid fertilizers such as UAN, ammonium polyphosphate (APP), ammonium thiosulfate (ATS), potassium thiosulfate (KTS), calcium nitrate (CN9) and others were not available until after the original study. Data from these materials have been added to data from the original study in the fertilizer salt index reference tables being used today.

Recent studies

Method comparison. In 2004, Murray and Clapp compared several potassium (K) sources for salt index values, as determined by the Jackson method, with the original data published by Rader. As noted in Table 1, salt index values from the two methods do not directly correlate. Some minor differences are noted as a result of differences in the K₂O concentration because Rader used chemically pure material for K₂SO₄ and KNO₃. In this study, a
Two Distinct Fluid Starter Types

- Ammonium polyphosphates
- 100% orthophosphates
Polyphosphates

• What are they?
• How they are produced?
• What they do and advantages to having “polys”?
• Precautions
Phosphoric Acid Sources

- Wet
- Thermal
- PPA
What is a polyphosphate?

- Polyphosphates are molecules containing more than one phosphorus atom
  - Prior to the advent of the TVA pipe reactor process they were very difficult to make
  - Only source lay in “high poly” superacids (which are very corrosive)
- Required high heat and high vacuum conditions
- 50% poly was about the most that could be achieved
The basic building block for polyphosphates
Using heat to drive out chemically bound water and link the phosphate molecules
With more heat additional links can be made each time removing another molecule of chemically bound water.
Where does the heat come from?
Ah-ha!

Figure 4

\[
\begin{align*}
\text{AMMONIA} & \quad + \quad \text{SUPER ACID} & \quad = \quad \text{HEAT} \\
\text{NH}_3 & \quad + \quad \text{H}_3\text{PO}_4 & \quad + \quad \text{H}_3\text{PO}_4
\end{align*}
\]
The overall process
Why Superacids?

• It’s difficult to produce polyphosphates from orthophosphoric acids because they contain so much “free” water
• Superacids contain no “free” water (they are anhydrous)
Benefits of the TVA pipe reactor process
(Developed in the mid-60’s)

1. Allowed production of High poly ammonium phosphate solutions
2. Eliminated the need for high poly superacids
THE TVA REACTOR
** Modifications Required **

- Add a plate & frame heat exchanger
- Add a pump - 50 hp - to recyle water
- Add cooling system for the water - evaporative tower or chiller
- Close in current tower - remove packing and fan
High Ortho

• N from ammonia, urea
• P from high grade orthophosphoric acid
• K from KOH
• S from ATS
• Micros from EDTA chelated sources

High Poly
High Ortho

- N from ammonia, urea
- P from high grade orthophosphoric acid
- K from KOH
- S from ATS
- Micros from EDTA chelated sources

High Poly

- N from ammonia, UAN
- P from polyphosphate (converted from super acid)
- K from KCl
- S from ATS + other
- Micros from ammoniated complexes, sulfates, chlorides and chelates
Plant Food Madness

• The market is becoming more diverse with blends
  – 30/70 ortho/poly—typical high polyphosphate
  – 50/50 ortho/poly
  – 60/40 ortho/poly
  – 70/30 ortho/poly
  – 80/20 ortho/poly
  – 100/0 ortho/poly

– We’re no longer “purists”

Blends are the growth area. K source can be KCl or KOH.
Ortho Benefits

• Plants use only ortho phosphate
• Immediately available phosphorus
• Higher ortho = lower viscosity for uniform flow rates over a wide range of temperatures
• Fewer contaminants to settle out
• 100% ortho—virtually no contaminants
• Excellent storability
Ortho Cons

- Does not sequester micronutrients
- Must use completely chelated micros
- Usually more expensive per unit of phosphate
Poly Benefits

- Concentrated P
- Sequesters micros (important for zinc)
- Cheaper acid raw material source
- So called “Contaminants” include micronutrients at no extra charge
Poly Cons

- Often not recommended for in-furrow placement depending on K source
- Polyphosphate chains need to break down (hydrolyze) for bio availability
- Higher Viscosity (due to concentration)
- Storability problems if Poly converts in the tank before use
Ortho vs Poly.pdf
Seed Safety

• High orthos tend to be built with monopotassium phosphate as raw material. 
  \((\text{ortho acid} + \text{KOH}) = \text{low salt index}\)
• Safer on the seed
• High poly fertilizers are usually built with potassium chloride for the K source. Lowest cost, but higher salt index. Avoid seed placement. Economical for other placements
Corrosiveness

• Important for equipment, especially planters
• Spend a quarter million dollars on a planter and what becomes the main concern if used for fertilizer application? Rust and corrosion!
• Foliar application gets fertilizer on equipment
• Generally, low salt index fertilizers made with monopotassium phosphate are also least corrosive to mild steel
Salt Index Basics

• The salt index (SI) is a **relative** measure of a fertilizer to draw moisture and compete with roots and plants for water

• The higher the fertilizer SI the greater the risk of injury to the plant.

• Germinating seeds are especially sensitive to fertilizer mixtures with a high SI

• SI values are based on sodium nitrate = 100
SI Basics (Cont’d)

• Each component of a mixture has its own SI
• The SI of fluid mixtures can be calculated from the SI values of its components
• The SI permits the comparison of fluid formulations using different components
• SI tables are available from a number of sources (Farm Chemicals Handbook; Professional Dealers Manual – ARA; Publications of the FFF)
SI Basics (Cont’d)

• Again, the SI of a mixture is the sum of the SI values contributed by each of its components.

• The SI for a “high analysis” NPK mixture may be greater than for a “low analysis” one --- however, the SI per unit of plant nutrient may be lower for the higher analysis product!

• Must compare mixtures on the basis of per unit of plant nutrient.
Calculating Salt Index Values

• **Step 1.** Determine the SI per unit of plant nutrient of each raw material
• **Step 2.** Calculate the total units contributed to the final mixture by each raw material
• **Step 3.** Multiply the above value (total units contributed) by the value found in Step 1
• **Step 4.** Repeat Steps 1, 2 and 3 for each raw material
• **Step 5.** Sum the contributions from each of the raw materials to find the SI of the total blend
### Salt Index Values of Fertilizer Materials

<table>
<thead>
<tr>
<th>Material and analysis</th>
<th>Salt Index Per equal wts of materials</th>
<th>Per unit of nutrients*</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>NITROGEN/SULFUR</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ammonia, 82% N</td>
<td>47.1</td>
<td>0.572</td>
</tr>
<tr>
<td>Ammonium nitrate, 34% N</td>
<td>104.0</td>
<td>3.059</td>
</tr>
<tr>
<td>Ammonium sulfate, 21% N, 24% S</td>
<td>68.3</td>
<td>3.252</td>
</tr>
<tr>
<td>Ammonium thiosulfate, 12% N, 26% S</td>
<td>90.4</td>
<td>7.533</td>
</tr>
<tr>
<td>Urea, 46% N</td>
<td>74.4</td>
<td>1.618</td>
</tr>
<tr>
<td>UAN, 28% N (39% a. nitrate, 31% urea)</td>
<td>63.0</td>
<td>2.250</td>
</tr>
<tr>
<td>32% N (44% a. nitrate, 35% urea)</td>
<td>71.1</td>
<td>2.221</td>
</tr>
<tr>
<td><strong>PHOSPHORUS</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>APP, 10% N, 34% ( \text{P}_2\text{O}_5 )</td>
<td>20.0</td>
<td>0.455</td>
</tr>
<tr>
<td>DAP, 18% N, 46% ( \text{P}_2\text{O}_5 )</td>
<td>29.2</td>
<td>0.456</td>
</tr>
<tr>
<td>MAP, 11% N, 52% ( \text{P}_2\text{O}_5 )</td>
<td>26.7</td>
<td>0.405</td>
</tr>
<tr>
<td>Phosphoric acid, 54% ( \text{P}_2\text{O}_5 )</td>
<td></td>
<td>1.613^a</td>
</tr>
<tr>
<td>72% ( \text{P}_2\text{O}_5 )</td>
<td></td>
<td>1.754^a</td>
</tr>
<tr>
<td><strong>POTASSIUM</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Monopotassium phosphate, 52% ( \text{P}_2\text{O}_5 ), 35% ( \text{K}_2\text{O} )</td>
<td>8.4</td>
<td>0.097</td>
</tr>
<tr>
<td>Potassium chloride, 62% ( \text{K}_2\text{O} )</td>
<td>120.1</td>
<td>1.936</td>
</tr>
<tr>
<td>Potassium sulfate, 50% ( \text{K}_2\text{O} ), 18% S</td>
<td>42.6</td>
<td>0.852</td>
</tr>
<tr>
<td>Potassium thiosulfate, 25% ( \text{K}_2\text{O} ), 17% S</td>
<td>68.0</td>
<td>2.720</td>
</tr>
</tbody>
</table>

^aSalt index per 100 lbs of \( \text{H}_3\text{PO}_4 \); *One unit equals 20 lb.

Mortvedt, “Calculating Salt Index”
## Calculating Salt Index of 6-24-6

<table>
<thead>
<tr>
<th>Material</th>
<th>% Nutrient</th>
<th>lbs/ton</th>
<th>N</th>
<th>P₂O₅ Nutrient units</th>
<th>K₂O Nutrient units</th>
<th>Salt index per unit (20 lb)a in formulation</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1)</td>
<td>(2)</td>
<td>(3)</td>
<td>(4)</td>
<td>(5)</td>
<td>(6)</td>
<td></td>
</tr>
<tr>
<td>NH₃</td>
<td>82%N</td>
<td>146</td>
<td>6.0</td>
<td>—</td>
<td>—</td>
<td>— b</td>
</tr>
<tr>
<td>H₃PO₄</td>
<td>54% P₂O₅</td>
<td>666</td>
<td>—</td>
<td>18.0</td>
<td>—</td>
<td>1.613</td>
</tr>
<tr>
<td>Potassium</td>
<td>22% K₂O</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>10.7</td>
</tr>
<tr>
<td>Phosphate</td>
<td>22% P₂O₅</td>
<td>546</td>
<td>—</td>
<td>6.0</td>
<td>6.0</td>
<td>0.097</td>
</tr>
<tr>
<td>Water</td>
<td>—</td>
<td>642</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td>2,000</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>6.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>24.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>6.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>11.9c</td>
</tr>
</tbody>
</table>

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a Salt index per unit (20 lb) of plant nutrients, listed in Table 1, also called the partial salt index.

b Ammoniation of phosphoric acid to a 1-3-0 ratio forms a mixture of MAP and DAP.

c 0.32 SI/unit plant nutrient.
### Calculating Salt Index of 7-21-7

<table>
<thead>
<tr>
<th>Material</th>
<th>% Nutrient</th>
<th>lbs/ton</th>
<th>N</th>
<th>P₂O₅</th>
<th>K₂O</th>
<th>Salt index per unit (20 lb)</th>
<th>in formulation</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1)</td>
<td>(2)</td>
<td>(3)</td>
<td>(4)</td>
<td>(5)</td>
<td>(6)</td>
<td>(7)</td>
<td>(8)</td>
</tr>
<tr>
<td>10-34-0</td>
<td>10% N, 34% P₂O₅</td>
<td>1,235</td>
<td>6.2</td>
<td>21.0</td>
<td>—</td>
<td>0.455</td>
<td>12.4</td>
</tr>
<tr>
<td>UAN</td>
<td>28% N</td>
<td>57</td>
<td>0.8</td>
<td>—</td>
<td>—</td>
<td>2.250</td>
<td>1.8</td>
</tr>
<tr>
<td>KCl</td>
<td>62% K₂O</td>
<td>226</td>
<td>—</td>
<td>—</td>
<td>7.0</td>
<td>1.936</td>
<td>13.6</td>
</tr>
<tr>
<td>Water</td>
<td></td>
<td>482</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2,000</td>
<td>7.0</td>
<td>21.0</td>
<td>7.0</td>
<td>27.8b</td>
<td></td>
</tr>
</tbody>
</table>

*a Salt index per unit (20 lb) of plant nutrients, listed Table 1, also called the partial salt index.

*b 0.79 SI/unit plant nutrient
Salt Index of Some Common Liquid Formulations

<table>
<thead>
<tr>
<th>Formulation</th>
<th>Salt Index</th>
<th>Salt Index per Unit of Plant Nutrient (20 lb)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2-20-20</td>
<td>7.2</td>
<td>0.17</td>
</tr>
<tr>
<td>3-18-18</td>
<td>8.5</td>
<td>0.22</td>
</tr>
<tr>
<td>6-24-6</td>
<td>11.5</td>
<td>0.32</td>
</tr>
<tr>
<td>9-18-9</td>
<td>16.7</td>
<td>0.48</td>
</tr>
<tr>
<td>10-34-0</td>
<td>20.0</td>
<td>0.45</td>
</tr>
<tr>
<td>7-21-7</td>
<td>27.8</td>
<td>0.79</td>
</tr>
<tr>
<td>4-10-10</td>
<td>27.5</td>
<td>1.18</td>
</tr>
<tr>
<td>28% UAN</td>
<td>63.0</td>
<td>2.25</td>
</tr>
</tbody>
</table>
Why SI is Important Today

- Row placement easier with large planters
- Need more seed safety
- Fertilizer openers on large planters have disadvantages
  - Expensive
  - Take extra horsepower
  - Obstruct trash flow in high residue conditions
  - Disturb seedbed in no-till
  - Seed depth variable because moist soil kicked out by fertilizer opener sticks to seed depth control wheels
Phosphorus Uptake by Corn as Affected by the Potassium Salt Added to Phosphate-Nitrogen Mixture in Band

<table>
<thead>
<tr>
<th>Formula</th>
<th>Compound</th>
<th>Salt Index (SI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>KH₂PO₄</td>
<td>Potassium Phosphate</td>
<td>0.10</td>
</tr>
<tr>
<td>K₂SO₄</td>
<td>Potassium Sulfate</td>
<td>0.85</td>
</tr>
<tr>
<td>KCl</td>
<td>Potassium Chloride</td>
<td>1.94</td>
</tr>
</tbody>
</table>

Source - How Roots Tap a Fertilizer Band by Prof. A.J. Ohlrogge
National Plant Food Institute, Washington, D.C.
Using Ortho and Poly in the field

- Rader said that salt index determines placement
- Far from seed—no concern about SI
- Strip-till: Poly P with high SI fertilizers applied preplant in subsurface band. Planter applied low SI 6-24-6 for safety in seed furrow
- Ammonia and 10-34-0 applied together in “dual band.” Plus planter applied low SI starter fertilizer in seed furrow
- Liquid or dry surface broadcast + row placed liquid, low SI ortho at planting
Ortho vs Poly: Summary

• Original liquid fertilizers were all ortho
• Plants use only ortho form
• High ortho products are typically more dilute
  – Flow better in cold temperatures
  – Lack sequestration power
• Polys naturally break down to form ortho P
• TVA pipe reactor process used concentrated acid and ammonia under high temperature to form high poly
• Most fertility programs include both.
Salt Index: Summary

• For seed placement (and foliar) or very close to the seed use low salt index products to protect expensive seed and leaf tissue
• Don’t want corrosion on equipment? Use low salt index fertilizer made from monopotassium phosphate. No chloride or nitrate
• Broadcasting or banding several inches from seed furrow-- look for economical alternatives
• Successful fertilizer programs include both low SI products and “conventional” fertilizers
Sulfur: Common Fluid Sources

• ATS 12-0-0+26S (ammonium thiosulfate)
• KTS 0-0-25+17S (potassium thiosulfate)
• K-Row 23® 0-0-23-8S. Supplies K and S. A product designed for blending with ammonium polyphosphate for seed safe application with pop-up fertilizers.
Micronutrients: Common Fluid Sources

- Zinc: Chelates, ammoniated zinc complexes, sulfates, nitrates, chlorides...
- Manganese: Chelates, sulfates,
- Copper: Chelates, sulfates, chlorides
- Iron: Chelates, sulfates
- Boron: Boric acid, Solubor®
## Chelates and micronutrients

<table>
<thead>
<tr>
<th>Chelating Agent</th>
<th>Micronutrients</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Copper</td>
</tr>
<tr>
<td>EDTA</td>
<td>X</td>
</tr>
<tr>
<td>HEEDTA</td>
<td>X</td>
</tr>
<tr>
<td>NTA</td>
<td></td>
</tr>
<tr>
<td>DTPA</td>
<td></td>
</tr>
<tr>
<td>EDDHA</td>
<td></td>
</tr>
</tbody>
</table>
Thank you!