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Four Points by Sheraton Denver Southeast
HOME BREWING WITH ALTITUDE
Beer Color and Residual Alkalinity: A Practical Example

John Palmer
Rick Bobbitt
Scott Jackson
Thank You!

- All malts provided by Briess Malting and Ingredients Co.
- Yeast provided by White Labs Inc.
- Hops provided by Morebeer.com

- All the work provided by Rick Bobbitt and Scott Jackson of KROC!
Why Water Matters

- The water and the malts drive the mash chemistry and the enzyme activity.
- Adding Brewing Salts Always Affects Flavor and pH.
- Calcium, Magnesium, and Carbonate affect pH.
- Sulfates accentuate hop bitterness, making it more crisp.
- Sodium and Chloride accentuate the malt flavors.
Review of pH

- The target mash pH range for **EVERY** beer, *regardless of style*, is: 5.4-5.8 @ room temperature.
- pH papers are made to be used on room temperature samples.
- pH meters with ATC adjust the measured pH of the sample *to the calibration temperature*.
- Calibration solutions are most accurate *at room temperature*. 
What does water pH mean?

pH can be interpreted as the ratio of negative ions to positive ions.

The water may seem Hard, but it’s usually Alkaline.
What is Hard Water?

- Hard water contains high amounts of Calcium and Magnesium. (et. al.)
- Hard water pH can range from 5-10.
  - Acidic (<7) or Alkaline (>7)
  - pH depends on the balance of hardness to alkalinity.
- Hard water is **GOOD** for brewing because calcium is an *important co-factor* for many brewing bio-chemical reactions.
What is Soft Water?

- Soft water does not contain high levels of calcium, magnesium, or other cations.
- Soft water pH can range from 7-10.
- Soft water can be alkaline, but alkaline water is not necessarily soft.
What does Water Softening Do?

- Salt-based Water Softeners exchange sodium ions for calcium, magnesium, iron, etc.
  - *Throwing the baby out with the bath water.*
- Water Softeners do not affect the alkalinity.
  - The result is *extra-alkaline water.*
Residual Alkalinity

Mash (and beer) pH is the net effect of the Hardness, Alkalinity, and the Grainbill.

- RA = alkalinity - (Ca/3.5 + Mg/7)
  - Units are mEq/L
- High RA means you should brew dark beers
- Low RA means you should brew light beers
Hardness, Alkalinity, and Grainbill acidity balance to determine your mash pH.
RA and Classic Brewing Waters

- Most water reports contain the individual annual averages for a particular mineral.
- As listed, all the minerals do not add up to a “real” water. A real water should have all the ion charges sum to zero.
- Check the RA for the Classic Waters, does it make sense?
# Famous Brewing Waters

Water Profiles From Notable Brewing Cities

<table>
<thead>
<tr>
<th>City</th>
<th>Calcium (Ca(^{+2}))</th>
<th>Magnesium (Mg(^{+2}))</th>
<th>Bicarbonate (HCO(_3^-))</th>
<th>Beer Style</th>
<th>RA (ppm as CaCO(_3))</th>
<th>Color Range (°SR)</th>
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</thead>
<tbody>
<tr>
<td>Pilsen</td>
<td>10</td>
<td>3</td>
<td>3</td>
<td>Pilsener</td>
<td>-6</td>
<td>-10</td>
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<tr>
<td>Dortmund</td>
<td>225</td>
<td>40</td>
<td>220</td>
<td>Export Lager</td>
<td>-3</td>
<td>5-10</td>
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<tr>
<td>Vienna</td>
<td>163</td>
<td>68</td>
<td>243</td>
<td>Vienna Lager</td>
<td></td>
<td>8-14</td>
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<tr>
<td>Munich</td>
<td>109</td>
<td>21</td>
<td>171</td>
<td>Oktoberfest</td>
<td>50</td>
<td>9-14</td>
</tr>
<tr>
<td>London</td>
<td>52</td>
<td>32</td>
<td>104</td>
<td>British Bitter</td>
<td>30</td>
<td>8-12</td>
</tr>
<tr>
<td>Edinburgh</td>
<td>100</td>
<td>18</td>
<td>18</td>
<td>Scottish Ale</td>
<td>50</td>
<td>9-14</td>
</tr>
<tr>
<td>Burton</td>
<td>352</td>
<td>24</td>
<td>320</td>
<td>India Pale Ale</td>
<td>-3</td>
<td>5-10</td>
</tr>
<tr>
<td>Dublin</td>
<td>118</td>
<td>4</td>
<td>319</td>
<td>Dry Stout</td>
<td>175</td>
<td>20-24</td>
</tr>
</tbody>
</table>

Numbers are given in parts per million (ppm). These numbers are ANNUAL AVERAGES.
Residual Alkalinity Nomograph

Usage Notes:
1. Assume an error of +/- .1 pH due to individual mash chemistry.
2. The actual pH of the mash at mash temperature (~150°F) is typically .35 pH less than it measures at room temperature.

Effective Hardness is the (Ca/3.5 + Mg/7) quantity.
What does the Nomograph Do?

- Calculates the Residual Alkalinity of your water based on your water report.
- It estimates the pH of a BASE-MALT-ONLY! mash (i.e., 100% 2 Row).
- It suggests a Color Range for Beers that you can brew with your water and your residual alkalinity to achieve the proper mash pH range i.e., 5.4-5.8 pH.
Brewing a Pale Beer...

Usage Notes:
1. Assume an error of +/- .1 pH due to individual mash chemistry.
2. The actual pH of the mash at mash temperature (~150°F) is typically .35 pH less than it measures at room temperature.
Brewing a Dark Beer...

Usage Notes:
1. Assume an error of +/- .1 pH due to individual mash chemistry.
2. The actual pH of the mash at mash temperature (~150°F) is typically .35 pH less than it measures at room temperature.
# Pale Mash RA worksheet

<table>
<thead>
<tr>
<th>Source Water</th>
<th>Calcium (ppm)</th>
<th>Magnesium (ppm)</th>
<th>Bicarbonate (ppm)</th>
<th>Sodium (ppm)</th>
<th>Chloride (ppm)</th>
<th>Sulfate (ppm)</th>
<th>Water pH</th>
</tr>
</thead>
<tbody>
<tr>
<td>(ppm)</td>
<td>0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
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<table>
<thead>
<tr>
<th>Target Water</th>
<th>Calcium (ppm)</th>
<th>Magnesium (ppm)</th>
<th>Bicarbonate (ppm)</th>
<th>Sodium (ppm)</th>
<th>Chloride (ppm)</th>
<th>Sulfate (ppm)</th>
<th>Water pH</th>
</tr>
</thead>
<tbody>
<tr>
<td>(ppm)</td>
<td>0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Target Residual Alkalinity</th>
<th>Mash Water Volume (gal)</th>
<th>Additional Eff. Hardness Needed</th>
<th>Additional Alkalinity Needed</th>
<th>Target RA Est. SRM (Low)</th>
<th>Target RA Est. SRM (Hi)</th>
</tr>
</thead>
<tbody>
<tr>
<td>-128.0</td>
<td>5</td>
<td>128.0</td>
<td>0.0</td>
<td>0</td>
<td>0</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Acid Adjustment</th>
<th>Bottle Conc.</th>
<th>Est. Acid-Only Mash Addition (ml)</th>
<th>Mash Water Addition (ml)</th>
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<tbody>
<tr>
<td>Hydrochloric</td>
<td>37%</td>
<td>4.0</td>
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</tr>
<tr>
<td>Phosphoric</td>
<td>10%</td>
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<td></td>
</tr>
<tr>
<td>Lactic</td>
<td>88%</td>
<td>4.1</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Salt Additions</th>
<th>Chalk CaCO3</th>
<th>Gypsum CaSO4 *2H2O</th>
<th>Calcium Chloride CaCl2*2H2O</th>
<th>Epsom Salt MgSO4 *7H2O</th>
<th>Baking Soda NaHCO3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amt Added (grams)</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>2</td>
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</table>

<table>
<thead>
<tr>
<th>Salt Contributions (ppm)</th>
<th>Calcium (ppm)</th>
<th>Magnesium (ppm)</th>
<th>HCO3 (ppm)</th>
<th>Sodium (ppm)</th>
<th>Chloride (ppm)</th>
<th>Sulfate (ppm)</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>132.0</td>
<td>24.6</td>
<td>76.8</td>
<td>28.9</td>
<td>127.5</td>
<td>250.4</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Adjusted Mash (ppm)</th>
<th>Calcium (ppm)</th>
<th>Magnesium (ppm)</th>
<th>Alkalinity as CaCO3</th>
<th>Sodium (ppm)</th>
<th>Chloride (ppm)</th>
<th>Sulfate (ppm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>132.0</td>
<td>24.6</td>
<td>62.9</td>
<td>28.9</td>
<td>127.5</td>
<td>250.4</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Effective Hardness</th>
<th>Residual Alkalinity as CaCO3</th>
<th>Est. SRM (Low)</th>
<th>Est. SRM (Hi)</th>
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</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>5</td>
<td>10</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Target Color (SRM)</th>
<th>Est. RA (low)</th>
<th>Est. RA (Hi)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>6</td>
<td>-49</td>
</tr>
</tbody>
</table>

5 grams Gypsum
5 grams Calcium Chloride
5 grams Epsom Salts
2 grams Baking Soda
Palmer Precipitous Pale Recipe

- 7 lbs. 2 Row Malt
- 2.5 lbs. Vienna
- 1 lbs. Briess Carapils
- 0.5 lbs. Caramel 40
- 0.75 oz. Horizon @ 60
- 0.5 oz Amarillo @ 30
- 0.5 oz Willamette @ 15

- OG 1.050
- 41 IBUs
- Color 6 SRM (Morey)
- White Labs WLP 001
  - California Ale
Usage Notes:
1. Assume an error of +/- .1 pH due to individual mash chemistry.
2. The actual pH of the mash at mash temperature (~150°F) is typically .35 pH less than it measures at room temperature.
Palmer’s Sweet 4N Stout Recipe

- 7 lbs Briess 2 Row
- 1 lbs. Roast Barley
- 1 lbs. Briess Carapils
- 0.5 lbs. Caramel 40
- 0.5 lbs. Caramel 80
- 0.5 lbs. Special Roast
- 0.5 lbs. Dark Choc. malt
- 0.5 lbs. Black Malt
- 1.5 oz Challenger @ 60
- 0.5 oz Willamette @ 15

- OG 1.050
- 36 IBUs
- Color 45 SRM (Morey)
- White Labs WLP 001
  - California Ale
### Stout Mash RA worksheet

**Salt Additions**
- Chalk CaCO3: 5 grams
- Gypsum CaSO4 *2H2O: 5 grams
- Calcium Chloride CaCl2 *2H2O: 5 grams
- Epsom Salt MgSO4 *7H2O: 5 grams
- Baking Soda NaHCO3: 5 grams

**Adjusted Mash**
- Calcium (ppm): 105.9
- Magnesium (ppm): 24.6
- Alkalinity as CaCO3 (ppm): 286.8
- Sodium (ppm): 72.3
- Chloride (ppm): 0.0
- Sulfate (ppm): 103.0

**Effective Hardness**
- Residual Alkalinity as CaCO3
- Est. SRM (Low)
- Est. SRM (Hi)

0.0 | 0.0 | 5 | 10

**Target Color (SRM)**
- Est. RA (low)
- Est. RA (Hi)

45 | 427 | 486

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5 grams Calcium Carbonate
5 grams Epsom Salt
5 grams Baking Soda
Stout Water Example

Usage Notes:
1. Assume an error of +/- 0.1 pH due to individual mash chemistry.
2. The actual pH of the mash at mash temperature (~150°F) is typically 0.35 pH less than it measures at room temperature.
The Experiment....

- Brew both beers with both waters:
  - Pale Ale with Pale Ale Water
  - Pale Ale with Stout Water
  - Stout with Stout Water
  - Stout with Pale Ale water
The Brewers....

Scott (not Steve) and Rick.
Experimental Procedure - Water

- Brewing water was built from *distilled* using packets of salts for 5 gallons, dissolved into the mash. *(They wouldn’t dissolve into the distilled water.)*

- The sparge water was distilled, and as such, would not change the mash pH appreciably.

- The remaining salt was added to the boil after sparging to make up the difference to achieve the intended water profile.
Action Shot 1

The Jackson Backyard Brewery
Basic Brewing Procedure for both styles:

- Mashed in with 4 gallons of water for 11–12 pounds of grain. (1.3-1.4 qts/lb.)
- Single Infusion Mash at 154°F (67.7°C) for 60 minutes.
- Mashed Out with 2 gallons of hot water (~165°F).
- Batch Sparged to collect about 7.5 gallons in the boil kettle.
Pale Fermentation

Pale w/ Pale  Pale w/ Stout
The Brewing of the Pale....

- **Pale Ale w/ Pale Water**
  - Yield 71%
  - OG 1.046
  - FG 1.009
  - AA = 80%
  - 5.5 Mash pH
  - 4.5 Beer pH

- **Pale Ale w/ Stout Water**
  - Yield 71%
  - OG 1.046
  - FG 1.010
  - AA = 78%
  - 6.1 Mash pH
  - 4.7 Beer pH
Pale Ale Tasting Notes:

- Pale with Pale water (4.5 pH)
  - Big head and very good retention
  - Malty, fruity, and hoppy aroma.
  - Clean, assertive, but non-astringent bitterness.
  - Smooth mouthfeel
Pale Ale Tasting Notes con’t:

- Pale with Stout Water (4.7 pH)
  - Large head that fades quickly.
  - Poor hop aroma, some diacetyl.
  - Harsh bitterness, astringent, minerally.
  - Malt flavor is shallow, mostly bitter.
  - Smooth mouthfeel up front, yet astringent finish.
  - Malt and bitterness are not balanced.
The Brewing of the Stout....

- Stout w/ Stout Water
  - Yield 69%
  - 4 gallons
  - OG 1.054
  - FG 1.016
  - AA = 70%
  - 5.4 Mash pH
  - 4.6 Beer pH

- Stout w/ Pale Water
  - Yield 66%
  - 4.5 gallons
  - OG 1.055
  - FG 1.018
  - AA = 67%
  - 4.9 Mash pH
  - 4.2 Beer pH
Fermentation of the Stout

- Pale Water (left)
- Stout Water (right)
Sweet Stout Tasting Notes:

- Stout with Pale water (4.2 pH)
  - Chocolate aroma, vegetal, solvent aromas
  - Creamy dark head that fades
  - Flavor is thin, sharp, vegetal, one dimensional roast
  - Mouthfeel is creamy, yet dry and thin.
  - Taste is one dimensional, too much roast.
Sweet Stout Tasting Notes con’t:

- Stout with Stout Water (4.6 pH)
  - Complex chocolate, coffee, dark caramel aroma.
  - Dark creamy head with great retention
  - Complex flavor, hint of smoke, fruity, roasty, low sweetness for a sweet stout (oh well)
  - Smooth and creamy mouthfeel
  - Lovely complex beer.
Thank You!