Intro to Water Chemistry

Key Brewing Water Ions

Flavor Affecting Ions

- Chlorine / Chloramine (HOCl / H_2NCl)
- Sodium (Na^+)
- Sulfate (SO_4^{2-})
- Chloride (Cl^-)

pH Affecting Ions

- Calcium (Ca^{2+})
- Magnesium (Mg^+)
- Bicarbonate (HCO_3^-)

Chlorine / Chloramine ($HOCl$ / H_2NCl)

- An undesired ion from water sanitation
- Reacts with beer to create chlorophenolics which impart a mediciny / band-aid flavor
- Preferred range: 0 ppm
- 1 Camden Tablet per 20 gallons will remove Chlorine and Chloramine in minutes

Wichita Water Average: 2.1 ppm

Chloramines are more common in larger municipal water systems as they have less of a “Chlorine” smell while still providing sanitation.

Chloramine removal by filtering, boiling, or standing water is very slow.

Iron, Manganese, Nitrate, Nitrite, and Sulfides are also undesirable, but are typically low as they affect the taste of drinking water as well.

Sodium (Na^+)

- Sour / Salty taste
- Accentuates flavor and imparts roundness when used with chloride
- Poisonous to yeast at high levels
- Preferred range: 0-100 ppm

Wichita Water Average: 94 ppm

Historical brewing waters were all under 60ppm
Gose beers may approach ~250 ppm of sodium, but is typically added post fermentation.

Sulfate (SO_4^{2-})

- Gives a sharper, dryer, fuller edge to hoppy beers
- High concentrations can give a sulfury aroma
- Preferred range: 0-150 ppm
  - Highly hopped beers can go as high as 350 ppm

Wichita Water Average: 72 ppm

Burton water profile sometimes shows sulfates as high a 600 ppm

Undersireable in high levels for malty beers, particularly continental lagers with noble hops

Sample ESB has approximatly 350 ppm sulfates

Chloride (Cl^-)

- Accentuates fullness and sweetness
- Improves beer stability / clarity
- Different than the disinfectant chlorine!
- Preferred range: 10-100 ppm

Wichita Water Average: 117 ppm

Higher end of range shouldn't be used with high sulfate levels to avoid harshness.
The minerally character of Dortmunder Export is in part due to ~130ppm chloride.

Sulfate to Chloride Ratio

- Two primary flavor ions are Sulfate and Chloride
- Ratio of SO_4^{2-} to Cl^- can shift perception of sweetness/maltiness and bitterness/dryness

Perception	SO_4/CL Ratio*
Very Bitter	>2
Bitter	2
Balanced	1.3
Malty	.75
Very Malty	.5

*for Chloride between 25ppm and 100ppm

At low levels, the ions have little effect.
At very high levels, they can overwhelm a beer.
Some American IPA's will push as high as 9:1

Calcium (Ca^{2+})

- Principle Ion in making water “Hard”
- Beneficial for mashing / enzyme activity
- Essential for yeast health
- Aids trub and yeast flocculation
- Preferred range: 50-100 ppm

Wichita Water Average: 28.3 ppm

Insufficient calcium can contribute to beerstone (calcium oxalate) formation…keep at least 40 ppm unless brewing pilsners / light lagers

Magnesium (Mg^{+})

- Secondary Ion in making water “Hard”
- Beneficial for yeast / enzyme activity
- Aids yeast flocculation
- Can also be used to lower mash pH (less effective)
- Sour bitterness at low concentration
- Astringent at high levels
- Preferred range: 0-30 ppm

Wichita Water Average: 14.3 ppm

Minimum of 5ppm aids yeast flocculation. However, not necessary to add Mg as barley / wheat grist will typically contribute at least 5ppm

Mg is only half as effective as calcium and should only be used to lower mash pH if flavor effects are desired.

Bicarbonate (HCO_3^-)

- Typical source of alkalinity for brewing water /pH's
- Acts as a buffer to malt acids produced during mashing – tends to raise pH
- In sparge water, will raise mash pH, which can result in astringency from grain (tannins, polyphenols, etc)
- Preferred range: depends…

Wichita Water Average: ~76 ppm
(92 ppm total alkalinity in ppm as $CaCO_3$ * 0.83)

Bicarbonate is part of the carbonate cycle – which consists of aqueous (dissolved) CO2, carbonic acid, carbonate, and bicarbonate
Bicarbonate will transition over time to either carbonate or carbonic acid depending on pH.

Residual Alkalinity

- Brewing specific term that accounts for the interaction of Ca and Mg with alkalinity
- Ca and Mg react with malt phytins to create "Acids" that neutralize alkaline ions
- Mg^{+} is half as effective as Ca^{2+}
- Useful in matching water to beer styles
  - Why hard water is good for brewing

$$RA(ppm) = Alkalinity(ppm) - \left[\frac{Calcium(ppm)}{3.5} + \frac{Magnesium(ppm)}{7}\right]$$

Introduced by German brewer Paul Kohlbach in the 1940's

Residual Alkalinity

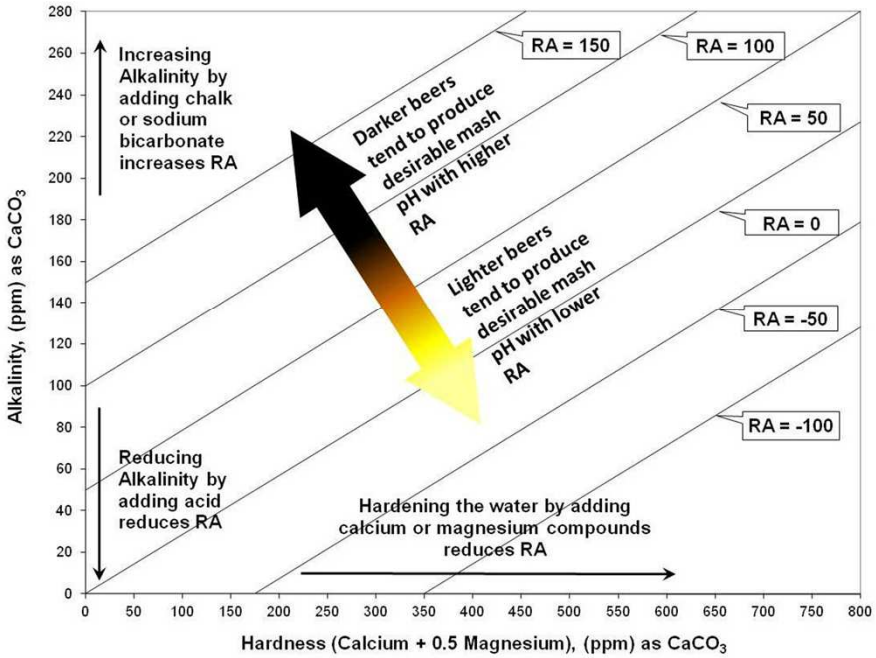

Chart from BrunWater and based on work by A.J. DeLange

Note that water with High Alkalinity and Hardness can be used with lighter colored beers (a la 'Burton' Water)
Also note – be careful trying to recreate famous "brewing waters" They may not be what the brewer used and in some cases the brewers had to work a lot to fix the "famous" water
Best thing: 1st, get the RA to match the beer style, second use the chloride/sulfate ratio to choose salt additions.

Water softeners remove Calcium and Magneisum and replace them with Sodium while leaving in the alkalinity Never use softened water!

Residual Alkalinity

- Acid production of grain is depending on grist composition.
- Different malt types have different acid production potential.
- These “Calculations” are really just estimates

Malt Acidity Relationships	
Malt Category	**Acid Production (mEq / lb of malt)**
Base	(0.28 x Lovibond Rating)
Crystal	(0.21 x Lovibond Rating) + 2.5
Roast	19
Acid	30

Numbers are derived based on research by Kai Troester, 2009

Mash pH

- pH affects wort character much like temperature
  - Effect is more subtle however
- Proper pH can:
  - Limit color increase (lighter color beer)
  - Faster fermentation and better attenuation
  - Greater stability (reduced oxidation)
  - More pleasant hop bitterness
  - “Fresher” “Crisper” beer
  - Better head stability
  - And others…

Grists with high amounts of Munich malt or other enzymatically weak malt should stay above 5.4 due to reduced alpha amylase activity below pH 5.6

Mash pH is also important as it affects boil pH. Higher boil pH can result in increased hop utilization (hop acids more soluble) However often reported to have a harsher character.

Resources:

- A.J. Delange - http://hbd.org/ajdelange/
- Kai Troester - http://braukaiser.com/
- Martin Brungard - https://sites.google.com/site/brunwater/home
- John Palmer – http://youtu.be/zJj__jEkFUE
  - Howtobrew.com

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