Water Chemistry

Actually, Mash Chemistry and the ions that matter.

Glen Napthali - October 2014

All grain vs Extract

- Water chemistry is significantly more critical to all-grain brewers. The composition and ultimately the pH of the water for the mash will affect the efficiency.
- For extract brewers you are using a concentrated mash syrup.
- Water profile will have a small impact on the final product, but there are more important things to get right first.

The ions that matter

- Cations
  - Calcium, Ca^{2+}
  - Magnesium, Mg^{2+}
- Anions
  - Sulphate, SO_4^{2-}
  - Chloride, Cl^-
- Other properties
  - Alkalinity
  - Hardness
  - pH

Calcium, Ca^{2+}

- Brewing Range = 50 - 150 ppm, with exceptions.
- 100 - 150 ppm Ca has been shown to be good for IPAs, good clarity, good body, etc.
- Calcium is the principal ion that determines water hardness.
- As it is in our own bodies, calcium is instrumental to many yeast, enzyme, and protein reactions, both in the mash and in the boil.
- It promotes clarity, flavour, and stability in the finished beer.
- Calcium additions may be necessary to assure sufficient enzyme activity for some mashes in water that is low in calcium.

Calcium, Ca^{2+}

- Ca reacts with phosphates extracted from the grain to lower the pH of mash.
- α-amylase is stabilized through the presence of calcium ions in the mash [Briggs, 2004].
- It is beneficial in high adjunct mash where a high α-amylase activity is desired to reduce the mash viscosity as much as possible.
- β-amylase stability is not effected by calcium ions and the concentration of calcium in the mash has no effect on the amount of fermentability of the produced wort.

Magnesium, Mg^{2+}

- Brewing Range = 10 - 30 ppm.
- This ion behaves very similarly to Calcium in water, but is less efficacious.
- It also contributes to water hardness.
- Magnesium is an important yeast nutrient in small amounts (10 - 20 ppm), but amounts greater than 50 ppm tend to give a sour-bitter taste to the beer. Levels higher than 125 ppm have a laxative and diuretic affect.
- Generally, it isn’t necessary to add to mash, sufficient is available from the grain.

Sodium, Na^+

- Brewing Range = 0 - 150 ppm, but keep it low as a rule.
- Sodium adds a "fullness" and "sweetness" to beer in reasonable concentrations. Keep under 100 ppm (usually under 50),
- The combination of sodium with a high concentration of sulfate ions will generate a very harsh bitterness. Too much (200 ppm) and it will be noticeable as “salty”.
- Sodium can occur in very high levels, particularly if you use a salt-based (i.e. ion exchange) water softener at home or ground water.

Chloride, Cl^-

- Brewing Range = 0 - 250 ppm.
- Chloride (Cl): Adds a "fullness" and accentuates maltiness. Chloride in excess of sulfate increases maltiness.
- Concentrations above 300 ppm (from heavily chlorinated water or residual bleach sanitiser) can lead to medicinal flavours due to chlorophenol compounds.

Sulphate, SO_4^{2-}

- Brewing Range = 50-150 ppm for normally bitter beers, 150-350 ppm for very bitter beers.
- Lends a dry, sometimes "sharp" character; accentuates hops. Sulfate in excess of chloride increases bitterness. Making the bitterness seem drier, more crisp.
- At concentrations over 400 ppm however, the resulting bitterness can become astringent and unpleasant, and at concentrations over 750 ppm, it can cause diarrhoea.

Alkalinity

- Brewing Range = 0 - 50 ppm for pale, base-malt only beers.
  50 - 150 ppm for amber coloured, toasted malt beers,
  150 - 250 ppm for dark, roasted malt beers.
- Controlling the alkalinity will control the mash pH.
- Higher alkalinity is required to offset the acidity of dark malts.
- Carbonate, bicarbonate and hydroxide are in equilibrium with each other depending on the pH of the water, in the range we are interested in the dominate form will be bicarbonate (HCO_3^{2-}).

Alkalinity

- Dilution is the easiest method of producing low carbonate water. Use distilled water from the in a 1:1 ratio, and you will effectively cut your bicarbonate levels in half, although there will be a minor difference due to buffering reactions.
- Boiling with Ca to form $CaCO_3$ precipitate is also an option.

Hardness

- Calcium, and to a lesser extent magnesium, combine with bicarbonate to form $CaCO_3$ which is only slightly soluble in neutral pH (7.0) water.
- The total concentration of these two ions in water is termed "hardness" and is most noticeable as carbonate scale on plumbing.
- Hardness as mg $CaCO_3$/L = 2.497[Ca mg/L] + 4.118[Mg mg/L]

pH

- Brewing range = 5.5 - 5.7 in Mash at room temperature (20°C).
- Ultimately the Ca, Mg, and alkalinity will control the pH of the mash and wort.
- For grain brewers getting the correct pH for the mash is as important as the mash temperature and grain crush.
- Mash pH will affect the efficiency and the flavours extracted from the grain, too high with a dark beer will produce more harsh astringent flavours.
- Too low pH will denature enzymes reducing starch conversion lowering efficiency. Even to the point of stopping conversion.

Hobart's water supplies

		Dover	Brighton	Clarence	Glen.	Hobart	Huon	Kingbo.
Ca	mg/L	4.2	11.5	10.6	10.5	10.3	10-20	5.8
Mg	mg/L	1.8	1.8	1.7	1.8	1.8	4-8	1.2
Na	mg/L	37	4.2	4.1	3.7	3.7	30-40	3.3
Cl	mg/L	18	8.3	8.7	8.3	7.7	10-20	6.3
SO_4	mg/L	48	7.6	8.2	7.7	7.7	35	2.2
Alkalinity	mg $CaCO_3$/L	27.5	24	22.6	23.2	21	50	13
Hardness	mg $CaCO_3$/L	18	36	33	34	33	40-80	19
pH		7.4	7.7	7.8	7.3	7.0	7.6	7.6
sd pH			0.6	0.5	0.6	0.6	0.3	0.9

Data provided by TasWater

Hobart's water supplies

- The data presented is the average from the previous 12 months testing, this is often only a couple of samples six months apart.
- Hobart's water is very soft with low alkalinity, this is a good thing, because we can build on it.
- It is similar to Pilsen, so to brew non-Pilsen styles you will need to add some Ca^{2+}, Cl^{-}, SO_4^{2-} and Alkalinity.
- It is recommended to add some buffering capacity to your water to control the effect of the grain acidity, allowing for a more stable mash pH.

Tank water and ground water

- Tank water can be assumed to be virtually pure H_2O, there will be dissolved minerals from dirt/dust on the roof and wind blown into the tank.
- Tank material can influence water quality. Concrete tanks will impart significant amounts of Calcium and Alkalinity. Gal tanks can add Zn.
- Ground water (bore, spring) will vary depending on the aquifer, if you want to use groundwater it will be necessary to have it tested and it can change seasonally. A cheaper option may be to buy water.
- In both cases keep an eye on the micro.

So what can be used to adjust the water profile?

- **Calcium Sulfate**, $CaSO_4.2H_2O$

  Gypsum

  1g/10L adds 23 ppm Ca and 56 ppm SO_4

- **Calcium Chloride**, available as $CaCl_2.2H_2O$

  Slight reduction in pH

  1g/10L adds 27 ppm Ca and 48 ppm Cl

So what can be used to adjust the water profile?

- **Calcium Carbonate,** $CaCO_3$

  Limestone, chalk

  Not very soluble

  Raises pH, increases alkalinity, useful for dark beers, helps to counteract the acidity of dark malt

  1g/10L adds 40 ppm Ca and 100 ppm Alkalinity as $CaCO_3$, but alkalinity change will not be direct due to the Ca extracting phosphates from the grain and offsetting some of the alkalinity.

So what can be used to adjust the water profile?

- **Sodium bicarbonate,** $NaHCO_3$

  Bicarb soda, baking soda (not baking powder)

  Raises pH, increases alkalinity, useful for dark beers, helps to counteract the acidity of dark malt

  1g/10L adds 27 ppm Na and 60 ppm Alkalinity as $CaCO_3$.

  Keep an eye on the Na especially with high SO_4.

So what can be used to adjust the water profile?

- **Sodium Chloride**, NaCl

  Table salt, canning salt, cooking salt.

  Can be used to add Cl without increasing the hardness/Ca

  1g/10L adds 39 ppm Na and 61 ppm Cl

- **Magnesium Sulfate,** $MgSO_{4.7H2O}$

  Epsom salts

  Generally not necessary.

  1g/10L adds 10 ppm Mg and 39 ppm SO_4

Useful references

- http://www.braukaiser.com/wiki/index.php

- **Calculators**
- http://www.brewersfriend.com/mash-chemistry-and-brewing-water-calculator/
- http://nomograph.babbrewers.com/index.html
- https://sites.google.com/site/brunwater/
- http://www.ezwatercalculator.com/

- **How to Brew by John Palmer**
- www.howtobrew.com