Brewing Water Chemistry 101

…..a brief introduction

SARANAC

MBAA Western New York
Rich Michaels, Quality and Innovation Manager
F.X. Matt Brewing Company
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Not all chemicals are bad.

Without chemicals such as hydrogen and oxygen, for example, there would be no way to make water, a vital ingredient in beer.

-Dave Barry

Why is water important?

Beer is typically 90-95% water

Historic brewing centers developed where the water was suitable for brewing.

Historic brewing styles developed around local water chemistry.

Today we have a huge advantage!

We understand water chemistry!
.....and we can change it!

Adjustments can be made by:

- filtration,
- softening,
- adding minerals,
- acid additions to reduce alkalinity, etc.

Proper pH is critical for many brewing chemical reactions.

These reactions occur in mashing, wort boiling, fermentation, aging and clarification.

We treat water to achieve desired pH in the brewing process and in finished beer.

The pH of the mash, wort and finished beer is important, not the water!

Basic Brewing Water Chemistry

Optimal pH ranges:

Mash pH (protein rest): 5.0-5.2

Mash pH (conversion): 5.2- 5.6

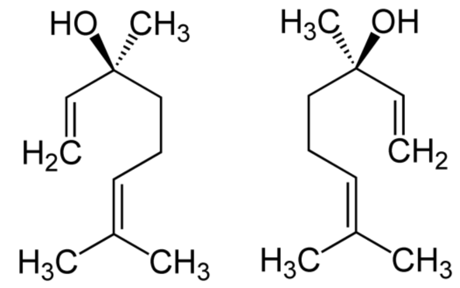
Kettle pH: 5.0-5.5

Beer pH: 4.2-4.6 (sour beers are lower)

Proper beer pH has an impact of beer stability.

For example, the hop aromatic linalool has two forms S-linalool and R-linalool. In hops about 93% of linalool is in the R form.

R-linalool has an aroma that is 90 times stronger than S-linalool.



R-linalool is transformed to S-linalool as pH decreases.

At 4.5 you may find 96% is the R from, at 4.0, the number drops to near 91% in the package.

- Dietmar Kaltner

Haze:

Beer haze formation is greatest slightly above pH 4 and is much weaker at both higher and lower pHs. – Karl Siebert

Proper beer pH has an impact of beer stability. (cont.)

Beer has a more rounded flavor above with a pH between 4.25 and 4.5.

For all malt beers a pH range of 4.25 - 4.6 is generally accepted as optimal.

– L. Narziss

According to Kalus Zastrow, pH should fall between 4.3 and 4.5.

Beer is less prone to oxidation at a higher ph.

Grigsby et al demonstrated that the tendency of beer to oxidize is less at higher pHs.

-Studies on the reactions involved in the oxidation of beer.
J. Am. Soc. Brew. Chem. 30: 87-92

Brewing Water Requirements

Microbiologically Clean - no bacteria

Free of metals - iron is a beer oxidizer and creates off flavors!

No aroma - no chlorine. We add chlorine to kill things - not ideal for growing yeast and many other flavor issues.

Soft water is a clean slate to work with,
but adjustments can be made to hard water.

First step: Know your water

Ask you municipality if you are on municipal water.

The analysis is free. Go to the front of the line if you bring them beer!

Send it to a lab for analysis.

Water can change seasonally.

Basic water analysis is affordable - for example Ward Labs brewing water analysis is less than $30.

There are local labs that can do the same testing.

DIY: Know your water

LaMotte Brew Lab water test kit - less than $200

Smartbrew Water testing kit – less than $300

Your existing spectrophotometer – less than $3 per parameter

Test for:

- Hardness
- Alkalinity
- Sulfate
- Chloride
- pH
- Calcium
- Magnesium
- Sodium
- pH

The Complete Water Analysis for Brewers

Sodium, Nitrate, Total Hardness

Calcium, Carbonate, Total Alkalinity,

Magnesium, Bicarbonate, Iron

Potassium, Sulfate, Phosphorus,

Chloride, pH, Total Dissolved Solids

Key Brewing Ions - Calcium

Calcium is important for mash enzyme stability, yeast flocculation and beer stability.

Without enzymes working as expected,
we can't make beer.

Yeast flocculation - clarity and filtration.

Low calcium can lead to oxalate crystals and gushing.

Ideally 50 - 150 ppm in brewing water.

Beer should have at east 50 ppm of calcium.

Key Brewing Ions - Magnesium

Magnesium is important yeast health.

Generally there is enough available in malt.

Too much can have a negative impact on flavor (astingency).

Too much can have a laxative effect (>125 ppm)

Ideally 0-50 ppm in brewing water

Key Brewing Ions - Sodium

Too much can have a negative impact of flavor .

> 150ppm can be salty and , mineraly and sour

Maximum should be 100 ppm

Ideally 0-50 ppm in brewing water

Key Brewing Ions - Potassium

Too much can have a negative impact of flavor- salty.

High levels can inhibit enzyme activity

Malt provides some, but not too much.

Common Mineral Additions

Calcium Chloride

Chloride ions accentuate malt character.

High concentrations (300 ppm+) can be unpleasant.

Calcium Sulfate (gypsum)

Sulfate ions accentuate hop bitterness. Makes hop bittiness sharper and crisper.

At high concentrations (400ppm+) the resulting bitterness can become astringent and unpleasant.

The key is balance!

Balance!

Sulfate to Chloride Ratio Impact on Flavor	
Perception	Sulfate : Chloride
Very Bitter / Dry	>2 : 1
Bitter	2 : 1
Balanced	1.3 : 1
Malty	0.75 : 1
Very Malty / Full	0.5 : 1

Waters of the World

Ion / City	Burton	Dortmund	Dublin	London	Pilsen	Munich
Calcium	275	230	120	70	7	77
Magnesium	40	40	4	6	2	17
Bicarbonate	270	235	315	166	16	295
Sodium	25	40	12	24	2	4
Chloride	35	130	19	38	6	8
Sulfate	610	330	55	40	8	18
SO4:Cl	17.4 : 1	2.5 : 1	2.9 : 1	1.1 : 1	1.3 : 1	2.3 : 1

Source – Martin Brungard – Bru'n Water

pH Adjustment by Food Grade Acid Addition

Per 100kg of malt add the following to reduce pH by approximately 0.1

Acid added	To the mash (g)	To the wort (g)
100% Lactic acid	58	29
80% Lactic acid	72	36
37% Hydrochloric acid	63	32
98% Sulfuric acid	32	16

Phosphoric acid can be used but may have a negative impact on calcium levels in finished beer.

Also, acidulated malt can be used.

Typically 1% acidulated malt will drop pH by 0.1

Quick and easy water adjustment method:

Narziss' Residual alkalinity method.

Dr. Ludwig Narziss studied water extensively.

This method will be a good start but watch out for high levels of chloride and sulfate if water is too alkaline.

This method just corrects alkalinity, not sulfate to chloride balance.

This is a good starting point for a pale beer, dark malts are acidic and therefore lower the pH of the mash

Narziss Residual Alkalinity Method

°pH (Narziss RA) correlates well as a predictor of wort pH in pale beers

°pH <1.0 will generally get you a good mash and wort pH

°pH = (Total Alkalinity x 0.056) - (Ca x 0.04) - (Mg x0.033)
(as ppm CaC03) - (as ppm Ca) - (as ppm Mg)

°pH adjustment:

25 ppm Ca++ (as Ca) reduces °pH alkalinity by 1

Mineral Additions

Calcium Chloride addition:

100 ppm of Calcium Chloride ($CaCl_2 \cdot 2\ H_2O$) added

will yield 27 ppm of Calcium and 48 ppm of chloride

Calcium Sulfate (gypsum) addition:

100 ppm of Gypsum ($CaSO_4 \cdot 2\ H_2O$) added

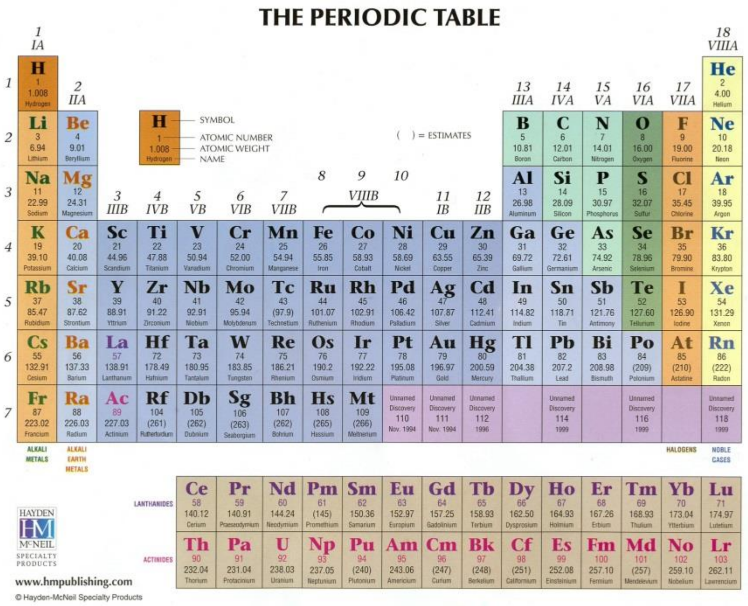
will yield 23 ppm of Calcium and 56 ppm of sulfate

As you can see chloride and sulfate can add up quick.

This shows a limitation to using this method with highly alkaline water.

Mass Calculations

Atomic Mass



Calcium - 40
Chlorine - 35.5
Oxygen - 16
Hydrogen - 1
Sulphur - 32

Gypsum and calcium chloride are dihydates.

$CaCl_2 \cdot 2H_2O$ and $CaSO_4 \cdot 2H_2O$

When you add it all up, $CaCl_2 \cdot 2H_2O$ has a mass of 147 and $CaSO_4 \cdot 2H_2O$ has a mass of 174

$CaCl_2 \cdot 2H_2O \rightarrow$ 40(Ca) divided by 147 = 27% of total

$CaCl_2 \cdot 2H_2O \rightarrow$ 71(Cl_2) divided by 147 = 48% of total

$CaSO_4 \cdot 2H_2O \rightarrow$ 40(Ca) divided by 174 = 23% of total

$CaCl_2 \cdot 2H_2O \rightarrow$ 96(SO_4) divided by 174 = 56% of total

Narziss Residual Alkalinity Example

Example - °pH = (Total Alkalinity x 0.056) - (Ca x 0.04) - (Mg x0.033)
(as ppm CaC03) - (as ppm Ca) - (as ppm Mg)

°pH = (47 x 0.056) – (6 x 0.04) – (0 x 0.033)

°pH = 2.632 – 0.24 = 2.392

Goal is to reduce °pH by 1.4 to 1.0

25 ppm x 1.4 °pH = 35 ppm of Ca

Sample ID : 2 BREWHOUSE

pH	8.9
Total Dissolved Solids (TDS) Est, ppm	93
Electrical Conductivity, mmho/cm	0.16
Cations / Anions, me/L	1.4 / 1.4
	ppm
Sodium, Na	23
Potassium, K	< 1
Calcium, Ca	6
Magnesium, Mg	< 1
Total Hardness, $CaCO_3$	19
Nitrate, NO_3-N	0.1 (SAFE)
Sulfate, SO_4-S	6
Chloride, Cl	5
Carbonate, CO_3	2.5
Bicarbonate, HCO_3	52
Total Alkalinity, $CaCO_3$	47

Narziss Residual Alkalinity Example Cont.

Adding 25 ppm x 1.4 = 35 ppm of Ca to get to a °pH of 1.0

For calcium sulfate / gypsum addition:

Divide 35 ppm by 23% to get 152 ppm $CaSO_4$

For calcium chloride:

Divide 35 ppm by 27% to get 130 ppm $CaCl_2$

ppm = parts per million or milligrams per liter

Narziss Residual Alkalinity Example Cont.

1	barrel is	117.34	liters			
1	ppm =	1	mg/L			
1	ppm x 117.34 =		117.34	mg		
	divide by 1000 =		0.11734	g		
CaSO4 Addition = 152 PPM						
	152	x	0.11734	17.8	g per barrel	
CaCl2 Addition						
	130	x	0.11734	15.3	g per barrel	

Brewing water chemistry is important and can be quite involved.

Getting it right will make a big difference in flavor and quality.

I encourage you to learn more. This presentation just scratched the surface.

There are many other resources –

Water (BA book) by John Palmer

Martin Brungard's website -sites.google.com/site/brunwater/

Kohlbach's work on water and residual alkalinity

etc.

Thank You!