Brewing Water

H_2O

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Water

- Typically about 90-95% of the beer
- It's not just dihydrogen monoxide
- Typically available from a number of sources:
  - Distilled water
    - pure H_2O, but not suitable for AG without treatment
    - probably recommended for extract?
  - Bottled
  - Reverse Osmosis (RO)
  - City water – may require treatment/filtration
  - Hose spigot – use RV hose
  - Well water – Know Your Numbers

City Water Treatment

- If your city water tastes fine, then there's no need to worry
- City water is disinfected with chlorine/chloramines
- These react with wort phenols to form chlorophenol off-flavours
  - Typically described as band-aid/antiseptic flavour
  - Perceived at very low levels (part per BILLION)
- Chlorine is easily boiled off
- Chlorine & chloramine can easily be removed within minutes by addition of ¼ Campden tablet/KMS in 5gal water
- KMS reduces chloramine to ammonium and chloride ions
  - both are beneficial to beer in the quantities generated by this.
  - The ammonium ion nourishes the yeast (FAN),
  - The chloride ion?… find out later

Water Chemistry

we need to talk about pH & ions

Chemistry Time - pH

- pH is a measure of acidity.
  - negative of $\log_{10}$ of the molar concentration of hydronium (H_3O^+) ions in water.
  - 1 pH difference is 10× more acidic i.e. pH 6 is 10× more acidic than 7.
  - Typically expressed on a scale from 0-14 pH.
- A pH of 7.0 is neutral - pure H_2O pH 7
- pH <7.0 is acidic - White vinegar ~ pH 3
- pH >7.0 is basic - Ammonia ~ pH 11.5
- Beer ~ pH 4

Beer pH Values

- 3.8 - 4.5 'normal' for most ales and lagers
  - Lagers tended to be around 3.9 - 4.1
  - Ales: 4.0 – 4.4 to achieve optimal taste and stability.
  - Mild/dark ales: 4.1 – 4.3
  - Sour beers: 3.1-3.8
- pH > 4.5 likely not ‘food safe’
  - Possibility of bacterial contamination
- pH 4.0 can start to create a thin drinking experience and even add an unintentional tartness

Water pH

- If pH is too high (basic) then food grade acid (phosphoric, lactic) can be used to acidify the water.
  - Should have a well calibrated pH meter to do this
- Acidified malts: 1% of Acidulated malt in the mash reduces the pH by ~0.1.
  - Acidulated Malt is produced by using lactic acid that is generated by the naturally occurring lactic bacteria on grain
- Water in the Kalamazoo area is slightly basic.
  - Good for stouts & darker beers.
  - Also very good for most other beer styles as well (look how many great breweries we have here!)
- Also quite hard (dissolved salts)

Water Hardness

- Hardness in water is caused by calcium & magnesium ions.
  - Total Hardness: combined concentration of calcium and magnesium.
- Temporary hardness
  - easily removed by boiling or through precipitation with lime (calcium hydroxide).
  - typically high in bicarbonates (forms carbonates)
- Permanent hardness is simply the hardness that is not removed by boiling water.
  - caused by chlorides, nitrates and sulphates of calcium and magnesium
  - these salts are highly soluble & are not precipitated by boiling.
- Water is often categorised according to the following degrees of hardness:
  - <75 ppm - soft
  - 75-150 ppm - moderately hard
  - 150-300 ppm - hard
  - > 300 ppm - very hard

Residual Alkalinity (RA)

- Residual Alkalinity (RA) determines how resistant water is to pH change.
  - If the RA is high, then more acid, (acidifed malts or acid addition) is required to adjust the pH.
  - Low RA indicates that the grain additions alone may be enough to get to the desired mash pH.

Water Warning

- Leaving pure (or RO) water standing for extended periods of time causes pH to lower
  - The moment water comes in contact with air, CO_2 gas begins dissolving into it, forming carbonic acid.
  - The actual pH, therefore, will often be <7.
  - Can occur using store bought distilled water: a friend had two brands and they were over a whole point different.
  - Another friend reported low mash efficiencies.

Mash Chemistry

how water affects the mash

Mash pH

- Grains are slightly acidic in the mash & naturally lower pH
  - dark grains are more acidic than lighter malts
- Mash pH should be in the range of 5.1-5.8
  - 5.2-5.6 is optimal for amylase enzyme activity.
  - pH >5.8, extracts astringent tannins from the grain husks.
- If pH is too high (basic) then food grade (phosphoric, lactic) acid can be used to acidify the sparge water during lautering.
  - Not recommended to correct mash pH directly due to buffering power of the mash.
- Incorrect mash pH range adversely affects conversion

Brewing Ions for Mash Chemistry

- Calcium (Ca^{2+}) 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.
- Magnesium (Mg^{2+}) is an important yeast nutrient in small amounts (10 -20 ppm), but >50 ppm imparts a bitter taste.
  - Seems unnecessary to add too much.
- Alkalinity (usually expressed as $CaCO_3$). Carbonate & bicarbonate are alkaline (neutralise acidity from dark malts) and are possibly the most important ions at controlling pH for all grain brewing.
  - The principal form for carbonates in wort is bicarbonate (HCO_3^-).

Brewing Ions Affecting Flavour

- Sulphate (SO_4^{2-}) accentuates hop bitterness, making it seem drier & more crisp. At concentrations over 400 ppm, the resulting bitterness can become astringent.
- Sodium (Na^+). At levels 70 - 150 ppm sodium rounds out the beer flavours & accentuates the maltiness; above 200 ppm the beer will start to taste... salty.
  - can occur in very high levels, particularly if using a home water softener.
- Chloride (Cl^-) accentuates the malty flavour and roundness and fullness in the beer.

Influence of Brewing Water

How cities' water influence their historical styles of beer

Water Styles of Historic Brewing Cities

- ppm=parts per million (1mg/1L).

City	Calcium (Ca^{2+})	Magnesium (Mg^{2+})	Sodium (Na^{+})	Sulphate (SO_4^{2-})	Chloride (Cl^{-})	Bicarbonate (HCO_3^{-})	Beer Style
Pilsen	10	3	3	4	4	3	**Pilsner**
Dortmund	225	40	60	120	60	220	**Export Lager**
Vienna	163	68	8	216	39	243	**Vienna Lager**
Munich	109	21	2	79	36	171	**Oktoberfest**
London	52	32	86	32	34	104	**British Bitter**
Edinburgh	100	18	20	105	45	160	**Scottish Ale**
Burton	352	24	44	820	16	320	**India Pale Ale**
Dublin	118	4	12	54	19	319	**Dry Stout**
Typical Range	50-150	10-30	0-150	50-150 150-350	0-250	0-50 50-150 150-250	
Balanced Profile	75	10	0-50	50-70	50-70	100	**Brewer's Friend**

How to Brew, John Palmer. Howtobrew.com

Local Water Numbers

- Water quality reports are primarily concerned with the safe drinking water laws regarding contaminants like pesticides, bacteria and toxic metals.
- As brewers, we are interested in the secondary or aesthetic standards that have to do with taste and pH.
- In Portage, we see quite a bit of variability in the ground water across the 11 local well fields. It appears that the same variability exists in Kalamazoo.
- The water being delivered to properties is typically blended from a number of different well sources to meet safe drinking water requirements
  - my house in Portage is a mixture being pumped from 3 well sites.
- KAR Labs offered a very good water report.
  - Pace Analytical seem to offer similar service
- Alkalinity refers to the total amount of bases in water expressed in ppm of equivalent calcium carbonate.
- Hardness is the concentration of metal ions (primarily Ca^{2+} and Mg^{2+}) expressed in ppm of equivalent calcium carbonate.

Local Water Results

Location	pH	Ca^{2+}	Mg^{2+}	SO_4^{2-}	Na^{+}	Cl^{-}	HCO_3^{-}	Hardness $CaCO_3$	NO_3^{-}	CO_3^{2-}	Alkalinity $CaCO_3$
Kalamazoo		85	33	40	36	74					
		102	30	42	36	74	188				
	7.72	120	32	40	36	117		350			286
Average	7.72	102	32	41	36	88	188	350			286
Portage	8.1	99	29	36	52	96	374	368	0.4	<1	310
	7.4	86.6	28	39	50	108	285	332	0.3	0.67	286
	7.5-8.0			36/27/49	63/41/149	119/68/303					
Average	7.8	93	29	38	51	102	330	350	0.4	0.7	298
Hillsdale Artisinal Well	7.4	82.4	23.3	15	11.4	20.1	312	302	1.4	0.74	313

Water Adjustments

aka why you're (hopefully) still listening

Methods to Adjust Water

- Dilution of tap water with RO/distilled water
  - Good for well water & city water
- Filtration – removes particulates & chlorine, but this won't affect your ions.
- Salt addition – for RO & dissolved water.

- In general, never use softened water for mashing (without adjustment); the wort needs the replaced calcium.
- Brewers in historical brewing cities often treated their water to add & remove minerals, or endured long complex mashes to overcome the issues their water caused.

Common brewing salts

- Sodium Chloride ($NaCl$)
  - source of sodium (Na^{+}) & chloride (Cl^{-})
- Baking Soda ($NaHCO_3$)
  - source of sodium (Na^{+}) & bicarbonate (HCO_3^{-})
- Calcium Carbonate ($CaCO_3$)
  - source of calcium (Ca^{2+}) & carbonate (CO_3^{2-})
  - Pretty insoluble
- Calcium Chloride ($CaCl_2$)
  - source of calcium (Ca^{2+}) & 2×chloride (Cl^{-})
- Calcium Sulphate ($CaSO_4$)
  - source of calcium (Ca^{2+}) & sulphate (SO_4^{2-})
- Epsom salts ($MgSO_4$)
  - source of magnesium (Mg^{2+}) & sulphate (SO_4^{2-})

1g/gallon salt additions

- i.e. if 1g of gypsum was added to 1 gallon of water, 61.5ppm of calcium & 147.4ppm of sulphate would be added
- if 10g gypsum was added to 5 gallons of water it would be double the ppm (123 Ca^{2+}, 294.8 SO_4^{2-})
- NB it is not possible to simply add calcium to your water; using calcium chloride means both calcium & chloride ions are added together.

	Ca^{2+}	Mg^{2+}	Na^{+}	SO_4^{2-}	Cl^{-}	HCO_3^{-}
Gypsum ($CaSO_4$)	61.5			147.4		
Table Salt (NaCl)			103.9		165.0	
Epsom Salt ($MgSO_4$)		26.1		103.0		
Calcium Chloride ($CaCl_2$)	72.0				127.4	
Baking Soda ($NaHCO_3$)			72.0			190.0
Chalk ($CaCO_3$)	105.8					158.4

Making Water Adjustments

- If you use city or well water, you NEED to know your water profile to be able to make any adjustments.
- Otherwise, 10G of RO water can cost <$5 for each brew day & <¢50 for salts.
- If you wanted to make the Kalamazoo water profile using distilled or RO water you'd make the following additions:

		Ca^{2+}	Mg^{2+}	Na^{+}	SO_4^{2-}	Cl^{-}	CO_3^{2-}
2.3g	$MgSO_4$		11.8		46.6		
2.9g	$CaCl_2$	41.7				73.8	
2.5g	$NaHCO_3$			36.7			96.9
2.9g	$CaCO_3$	60.7					90.9
	Total	102.4	11.8	36.7	46.6	73.8	187.7
	Kalamazoo	102.0	30	36.0	42.0	74.0	188.0
	Difference	0.4	-18.2	0.7	4.6	-0.2	-0.3

Sulphate: Chloride ratio

- Sulphate promotes bitterness of hops
- Chloride promotes malty character
- Playing with the ratio will affect the perception of the beer
  - Higher sulphate, more bitter
  - Higher chloride it'll be maltier
  - 1:1, your water will lend a balanced character to the beer.
  - 1.5:1 will emphasise the hop character.
  - >5:1 the hop character will be accentuated to the point that most drinkers find it unpleasant.
  - For NEIPAs, it's common to see the ratio more towards the chloride i.e. 1:3
    - Accentuates the maltiness & body of the beer over bitterness
- Usually altered by adding calcium chloride ($CaCl_2$) and calcium sulfate ($CaSO_4$)
- Keep within recommended ranges for the style

Measuring water

- pH
  - Strips or meter
  - Strips easier, but not as accurate
  - Meter expensive & time consuming
  - Calibration, storage
- Total Dissolved Solids
  - Conductivity – indicates dissolved minerals

TL;DR version?

- Most brewers in SW MI that I've spoken with don't worry about this they just filter & boil their brew water to remove chlorine & chloramine.
- One brewery asks their city to warn them when they flush their water lines as this can raise the chlorine/chloramine to undesirable levels.
- Kalamazoo breweries makes great beer with City water, so don't worry about it too much.
- Avoid using softened water, it's low on calcium salts & higher in sodium.
- At 2016 HBC, somebody spent 40 mins talking about this and basically said, "if you add about 10g of calcium salts to your RO mash water, you should be good".
- RDWHAHB; adding brewing salts is not necessary and is a matter of the style of the beer as well as the brewer's taste.

Simple additions for RO water

- Pale ale or IPA
  - adding 7 grams of gypsum to 5 gallon batch will provide 63 ppm of calcium and 148 ppm of sulphate.
  - desirable range for both calcium and sulphate for a hoppy beer.
  - also likely to give an optimum mash pH as well.
- Malty beers
  - Adding 3 grams of calcium chloride to a 5 gallon batch of Octoberfest *or brown ale* maybe be just the ticket to improving a brew.
  - chloride enhances the fullness or “roundness” of malt flavor, and gives a perception of sweetness to the beer.
- European style lagers
  - less sulphate is desirable and often it is completely left out.
  - It wouldn’t be unusual to brew a German pilsner without any additions to RO water at all.
- Stouts
  - Dark, roasted malts are acidic; the mash pH will need to be raised when sing RO.
  - Add 2-3 grams of baking soda to 4.0 gallons mash water should raise mash pH to desired levels.

https://www.brewersfriend.com/2018/02/13/brewing-water-basics-putting-it-all-together/

What do I do?

- Depends on style of beer

- Stout, IPA I typically use from outdoor spigot with RV hose & under sink filter
- NEIPA, lagers etc. build profiles with RO & salts
- Cut city water with RO (approx. 50/50)
  - Possibly add chloride/sulphate to accentuate flavours
- Lamotte test kits

Calculation Tools

- Spreadsheets:
  - EZ Water: http://www.ezwatercalculator.com/
  - John Palmer's Water Calculator: http://howtobrew.com/assets/img/assets/Palmers-Water-Adj-Gallons-4pt0.xls
  - Now available as an app!
  - Bru'n Water: https://sites.google.com/site/brunwater/
- Website:
  - Brewer's Friend https://www.brewersfriend.com/water-chemistry/
- Software:
  - BeerSmith http://beersmith.com/
  - BreWater program: http://www.brewater.net/download.html

Recommended Reading

- John Palmer & Colin Kaminski - Water: A Comprehensive Guide for Brewers
- Almost anything by John Palmer
- Ditto Randy Mosher
- A Brewing Water Chemistry Primer by AJ deLange https://www.homebrewtalk.com/showthread.php?t=198460/
- Water Knowledge by Martin Brungard https://sites.google.com/site/brunwater/water-knowledge

Reverse Osmosis Water

- Next best thing to distilled water
  - 'as pure' as you're likely to get it
- Removes approx. 95% to 99% of the dissolved salts
- Possibly recommended for extract brewing?
  - ions present in malting water will remain in the extract
- Uses pressure & membrane to purify the water
- Waste water (brine) higher in dissolved ions

- RO & distilled water will require salt additions for brewing requirements