BREWING WATER BASICS

BACKGROUND

Brewing water chemistry is important because it impacts:

1. The **chemical and biochemical processes** that occur during mashing and fermentation.
   For example, mash pH is influenced by the mineral content of the brewing water, which in turn impacts enzyme activity and as a result mashing efficiency.
2. The **perceivable taste** of the final beer.
   For example, the SO_4^{-2}:Cl^- (sulphate : chloride) ratio impacts the perceived bitterness/dryness of beer.

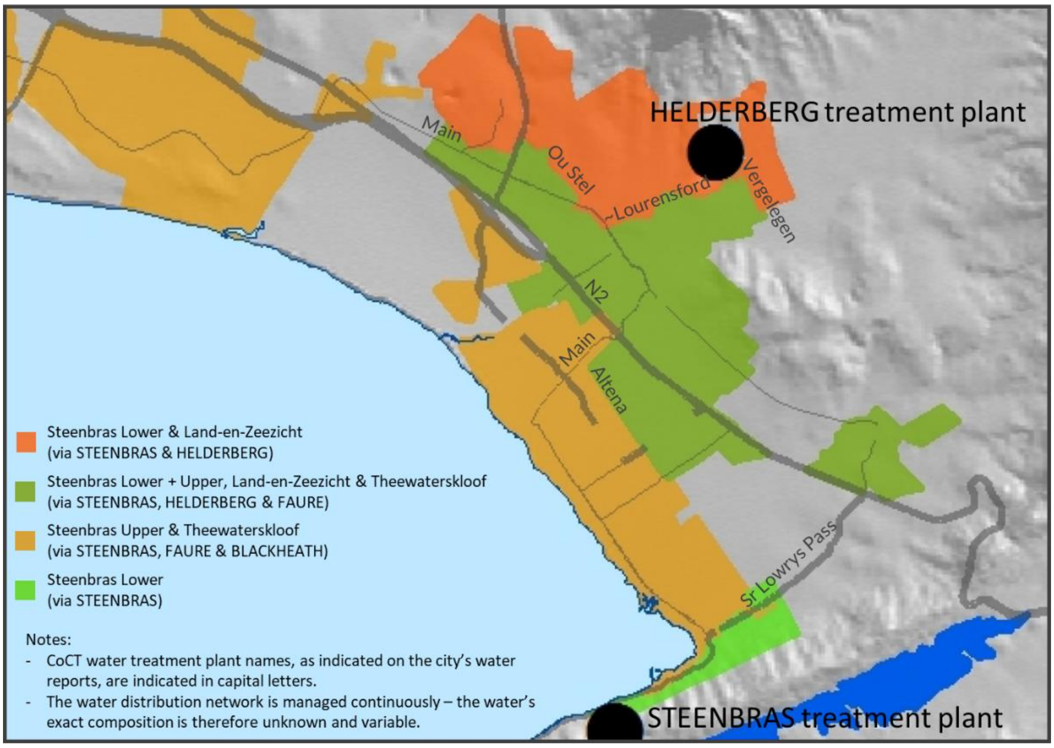
Brewing water quality management basically involves three steps:

1. **Remove the free Cl_2** (chlorine) if you use treated tap water (municipal water).
2. **Match your brewing water's residual alkalinity (RA) to the colour of beer** you want to brew to ensure mashing will take place at the correct pH (5.2-5.5) – generally, a higher RA is required for darker beers and vice versa.
3. **Adjust the ion concentrations and ion-ratios** as required for the specific beer style you are brewing.
   (In practice 2 & 3 happens simultaneously when you determine requirements and add salts.)

HELDERBERG TAP WATER

Helderberg tap water is sourced predominantly from dams and then treated and supplied by the City of Cape Town (CoCT). A map indicating the approximate origin (both in terms of dams & TREATMENT PLANTS) of the tap water in the Helderberg is presented below. Refer to the CoCT's annual water reports for more details on the chemical content and quality of the water. **Generally speaking, the Helderberg has good quality, soft (20-60 mg/L $CaCO_3$) water.**

APPROXIMATE ORIGIN OF HELDERBERG TAP WATER



Notes:

- *Prepared ("bottled") water is usually deionised/demineralised through the process of reverse osmosis (RO) which removes most of the dissolved ions from water - RO water is therefore very soft (typically <10 mg/L $CaCO_3$).*
- *Water softeners basically replaces calcium (Ca) and magnesium (Mg) ions with sodium (Na) ions and should NOT be used for brewing.*

DECHLORINATION

Municipal water is generally disinfected with chlorine and/or chloramine which may react with phenols in the malt to produce chlorophenols, resulting in a plastic-/medicinal-/Band-Aid-like off-taste and aroma in beer. Free chlorine and chloramine should therefore be removed from municipal tap water BEFORE using it for brewing.

Free chlorine can be removed by running your brewing water through an activated charcoal filter, boiling it for 15min, letting it stand overnight in an open container and/or treating it with sodium (or potassium) metabisulfite. Although free chlorine is effectively removed by any of these techniques, chloramine is NOT and should always be treated with sodium (or potassium) metabisulfite.

The CoCT confirmed (Jan 2022) that they only use chlorine, NOT chloramine, to treat the city's water. Any of the above-mentioned techniques can therefore be used to effectively remove the free chlorine from Helderberg tap water. However, adding sodium (or potassium) metabisulfite is so easy, cheap, and effective that it is recommended to always treat your tap water with it, even in addition to any of the other treatments.

In theory, only 1.34 mg sodium metabisulfite is required to remove 1 mg of chlorine, in practice however, 3 mg is used per mg chlorine. **Helderberg water contains approximately 1mg/L free chlorine, you therefore only need 75mg (0.075g) to effectively treat 25L of water (3 mg/L).**

Additional notes:

- *A Campden tablet contains ~440mg sodium metabisulfite and is typically used to treat 75L water - equivalent to 6 mg/L sodium metabisulfite.*
- *Other possible sources of chlorine when brewing are untreated rinse water and hypochlorite-based disinfectants like Jik.*
- *Sodium and potassium metabisulfite are widely used for preserving food and beverages (at ~100x higher concentrations) and they are also antioxidants.*

HARDNESS, ALKALINITY, AND pH

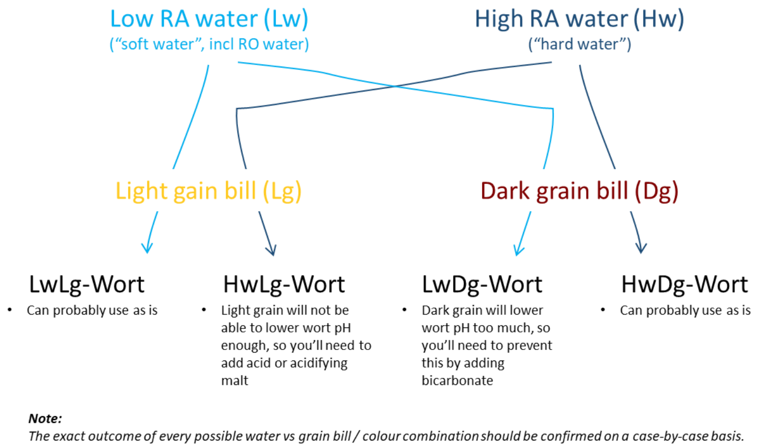
Hardness, alkalinity, and pH are interrelated chemical properties of water that impact both the brewing process and the taste of the resulting beer. A broadly accurate (some details are approximated), beer-specific overview of these properties is presented in table format below.

Property	Definition and explanations	Role and impact on brewing / beer
Hardness	• **A measure of the amount of dissolved multivalent cations in the water**, primarily calcium (Ca^{2+}) and magnesium (Mg^{2+}) - water hardness is commonly associated with soap's inability to foam in it. • As these ions are derived from the rocks the water has contact with, hardness is geology (region) dependent and predominantly caused by Ca^{2+}, a major element in many rocks • Water hardness is therefore expressed as equivalents of calcium carbonate ($CaCO_3$) in mg/L • General categories - Soft: ≤ 60 mg/L $CaCO_3$ - Moderately hard: >60 ≤ 120 mg/L $CaCO_3$ - Hard: >120 ≤ 180 mg/L $CaCO_3$ - Very hard: >180 mg/L $CaCO_3$	• Direct impacts include a potential **influence on beer flavour and mouthfeel** due to the high amounts of dissolved minerals in hard water (think of the brackish taste of hard Karoo water) **and reducing mash pH** (as reflected in the residual alkalinity calculation, see below) • Gives an indirect indication of how mash pH may be influenced by the grain bill • Generally speaking, brewing water should be moderately hard
Alkalinity	• **A measure of water's capacity to resist a reduction in pH when acidic compounds are added to it** – also called "buffer capacity" • Represents the amount of alkaline substances like carbonates (CO_3^{2-}) and bicarbonates (HCO_3^-) dissolved in water, originating from rocks and dissolved carbon dioxide (CO_2), which neutralise acids	• **Melanoidins in malt**, which result from the kilning and/or roasting process, **are acidic and therefore acidifies wort** • **Water with low alkalinity, which is unable to resist the acidification caused by the malt, will therefore acidify more** (measured as a drop in wort pH) **than high alkalinity water** • The amount of melanoidins in a malt, and therefore its ability to acidify wort, is directly related to its colour – darker beer grain bills acidify the wort more than lighter ones

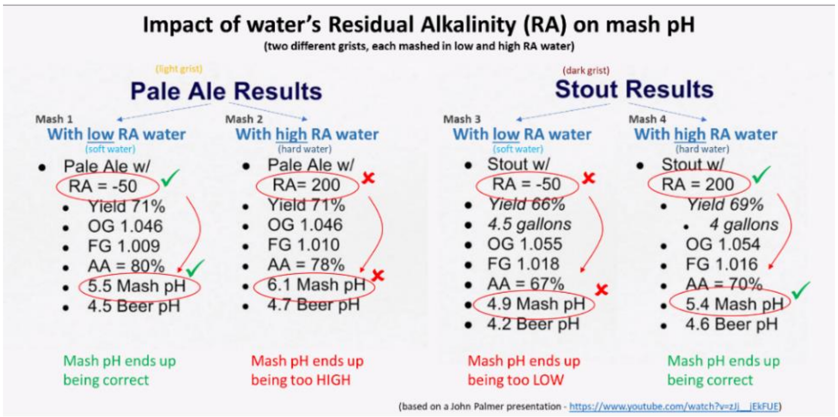
	• Alkalinity is also expressed as equivalents of $CaCO_3$ in mg/L	• Alkalinity can be increased with $Ca(OH)_2$ (pickling lime) or baking soda ($NaHCO_3$) and decreased with acids like hydrochloric acid (HCl), lactic acid, phosphoric acid or citric acid
Residual alkalinity (RA)	• **A brewing-specific parameter which is used to accurately predict mash pH** - it is derived from the difference between the brewing water's alkalinity and hardness • $RA \approx alkalinity - (\frac{hardness}{3})$	• Used to **estimate the brewing water's effect on the mash pH for a specific grain bill** (colour) and if there is a need to pro-actively adjust the water chemistry to ensure the eventual mash pH will be in the desired range (~pH 5.2-5.5) • Generally, water with higher RAs combined with darker grain bills (dark beers), result in mashes with the desired pH; similarly low RA water and light grain bills result in the correct pH (see graphics below)

Notes:

- *Alkalinity and hardness measure distinct chemical characteristics of water, however, they are related through common compounds like $CaCO_3$ which yields the counter-ions – Ca^{2+} for hardness and CO_3^{2-} for alkalinity. Moreover, $CaCO_3$ is the dominant water-soluble compound in many natural water systems because of the dominance of $CaCO_3$-based rocks like limestone and dolomite - hardness and alkalinity can therefore, to a limited extent, be used interchangeably.*
- *The interrelationship between water's hardness/alkalinity and wort pH when using different coloured grain bills is represented graphically below*



- *The below empirical data illustrate these impacts using low and high RA water for both a light (Pale Ale) and a dark (Stout) grist.*



pH	• **Measure of how acidic or basic a solution is** – technically the concentration of hydrogen ions (H^+) • Measured on a 14-point scale where 7 is neutral, <7 is acidic, and >7 is basic.	• When discussing pH in a brewing context, it is important to realise that **it is the pH of the mash, wort, and beer which is important, not that of the brewing water itself** • Enzymes typically have narrow pH ranges within which they are active, mash pH therefore needs to be managed to ensure it falls within the optimal range for all the relevant mashing enzymes, i.e. pH 5.2 - 5.5, to get the best possible conversion of starches to sugars • Beer pH can have a dramatic impact on flavour perception. Research has shown that pH changes of 0.2 units are apparent in the flavour of pale ales, with a pH of 4.2 yielding the best flavour

		• Other impacts of pH include: - A too high pH increases the solubility of tannins which leads to astringency and dry tasting beer - An acidic wort pH (5-6) improves hop extraction rates during the boil, yeast health during fermentation and inhibits bacterial growth - The correct pH improves protein and polyphenol precipitation both during the cold break and post fermentation, the clarity of the final beer with reduced chill haze and the flavour and clarity stability as beer ages

pH during the brewing process

	Mashing ⇨	Sparge ⇨	Boil ⇨	Fermentation ⇨	Beer
Ideal pH	5.2-5.5 (preferably closer to 5.2)	<6	5.0-5.2 (post-boil)	4.0-5.2 (decreases during fermentation)	<4.4 Most lagers 4.2-4.6 Most ales 4.0-4.4 Wheat beers 3.8-4.0 Sour beers ~3.0

Additional notes:
- *pH decreases during the brewing process, firstly because of the precipitation of calcium salts during mashing and boiling and secondly, because of the production of acids during fermentation.*
- *Mash pH determines to a large extent the pH during each subsequent step and that of the final beer. It is therefore important and worth the effort to ensure the correct pH during this first step.*
- *Generally, dark beers benefit from the upper end of this range, while pale beers benefit from the lower end. Within limits a low beer pH results in a crisper, livelier beer while a high beer pH is generally associated with a muted flavour perception.*

THE MOST IMPORTANT IONS IN BREWING

1. HCO_3^- & CO_3^{2-} (bicarbonate & carbonate): must be 25-50 ppm for pale beer and 100-300 ppm for darker beers. These two carbonate forms are always in equilibrium that depends on pH - bicarbonate dominates at brewing pH values. Primarily responsible for alkalinity of brewing water and therefore impacts mash pH significantly.
   - Add in form of $NaHCO_3$ (baking soda). (Reduce alkalinity through addition of acids.)
2. Ca^{2+} (calcium): must be 50-150 ppm. Principle ion causing hardness & important co-factor in many brewing bioprocesses and promotes clarity, flavour, and stability in the finished beer. Too high Ca will impact clarity and reduce fermentation efficiency. Too low may impact flocculation.
   - Add Ca in form of $CaSO_4$ (Gypsum) or $CaCl_2$ (calcium chloride).
3. Mg^{2+} (magnesium): must be 10-30 ppm. It accentuates flavour with a sour-bitterness when present at low concentration, but it is astringent at high concentrations. Important co-factor for enzyme activity and yeast growth.
   - Add Mg in form of $MgSO_4$ (Epsom salt / magnesium sulphate) or $MgCl_2$ (magnesium chloride).
4. SO_4^{2-} (sulphate): must be 50-350 ppm. Provides a sharper, dryer, bitter edge to highly hopped beers. More SO_4 for hoppiness and bitterness, e.g. 300:100 ppm SO_4:Cl (3:1). Becomes astringent and unpleasant >400ppm. Normal levels are 10-50 ppm for pilsners and light beers and 30-70ppm for most ales.
   - Add in form of $CaSO_4$ (gypsum) or $MgSO_4$ (Epsom salt).
5. Cl^- (chloride): must be 10-100 ppm. Accentuates fullness/body/roundness (mouthfeel) & sweetness and improves beer stability and clarity. More Cl for maltiness & body, e.g. 100:150 ppm SO_4:Cl (1:1.5).
   - Add in form of $CaCl_2$, $MgCl_2$ or NaCl.
6. Na^+ (sodium): must be 10-150 ppm, 10-70 ppm is typical. Rounds out the beer flavours, accentuating the sweetness, and contributes body and mouthfeel. At >200 ppm saltiness will become too prominent.
   - Add Na in form of NaCl (only use NON-iodised table salt).

Notes:
- *Parts per million (ppm) ≡ mg/L*
- *Ion concentrations are unlikely to ever be too high in the Helderberg's soft water, however the only way to reduce ion concentrations is through dilution with RO water - or alternatively use RO water to brew with and build your target chemical profile from that blank canvas.*

IN PRACTICE

So how do you apply all this information in practice?

Step 1 **Get hold of a water report** to confirm the chemical profile of your source water (see examples below).
Step 2 **Decide on an appropriate target profile** for the specific beer you're brewing. Based this on the colour of the beer (grain bill) and your preferred ion concentrations and ratios (depending on beer style).
Step 3 **Use a water chemistry calculator to determine how much of which salts must be added** (and possibly acids – unlikely for soft water) to your source water to end up with the target profile. Most brewing apps have such calculators, or you can use Brewer's Friend online "Advanced Water Chemistry Calculator" (see link below).
Step 4 **Add the required salts to your brewing water** – for both the strike & sparge water (it may be easier to dissolve the salts in the total volume of water and only remove the sparge water thereafter).

A Helderberg-specific profile, "**Helderberg water chemistry calculator**", containing the "Helderberg Supply" water profile (of June 2021), is available on brewersfriend.com as record ZK9XMC2 or via the following link - https://www.brewersfriend.com/mash-chemistry-and-brewing-water-calculator/?id=ZK9XMC2

How to use the Brewer's Friend water calculator

Note: Phrases in bold below refer to corresponding sections in calculator.

Step 1 Select correct **Water Volume**.
Step 2 Add or edit the **Source Water** profile according to your water report (pls save as a new record if you edit this one).
Step 3 Select required **Water Target** profile, e.g. "Light coloured and hoppy" or add your own target profile (from a recipe, for example).
Step 4 Enter **Grist Info** - the "*Beer color*" option works easiest.
Note that you must scroll down 6 sections to do this before coming back to add the required salts as described in Step 5. Moreover, you are unlikely to ever use the 5 sections between these two.
Step 5 Do virtual **Salt Additions** based on the differences between the source and target profiles – indicated in "*Delta*" line in the **Water Target** section. Basically, play around to get as close as possible to target profile, e.g. if both Ca and SO_4 is required, add a few grams of gypsum, and check what impact it has. Add baking soda ($CaCO_3$) if your grist is dark and the pH, indicated in the **Mash Report**, is too low. Continue until the pH is within range and all ions are close enough to the targets (see Step 6).
Step 6 Verify if all parameters are correct in the **Mash Report**.
- Predicted Mash pH should be correct (5.2-5.5) – marked with an ✓ if correct.
- All ions should be within the "*normal*" range – marked with a ★ if correct.

Step 7 Brew!

Example water profiles

Listed below are Helderberg tap and RO water profiles (source water) and three contrasting target water profiles to compare their different ion concentrations, alkalinity, and residual alkalinity (RA).

WATER	CHEMICAL PROFILE									
	Ca^{+2}	Mg^{+2}	SO_4^{-2}	Na^{+}	Cl^{-}	HCO_3^{-}	CO_3^{-2} #	pH	Alkalinity	RA
Source: Helderberg Supply (tap water)	9.6	2.3	6	16.7	35	(30.5)	(0.35)	8.4	28	(19.8)
Source: Oasis RO water (all values <)	2	0.1	2	3	5	(3.0)	(0)	6 - 8	5	(3.5)
Target: Pilsen (Czech Pilsner) *	7	3	5	2	5	25	(0)	-	23.4	(16.7)
Target: Light & hoppy (APA)*	75	5	150	10	50	30	(0)	-	27.6	(-28.8)
Target: London (Porter)*	100	5	50	35	60	265	(0)	-	223.0	(148.8)

#Negligible amounts of CO_3^{-2} < pH 9. *From Brewersfriend.com. Values in brackets were calculated. -pH of target water itself is irrelevant.

CONCLUDING REMARKS

Traditionally, softer water is considered optimal for making lighter, crisper beer. IPAs and clean lagers with rounded palettes are often made with soft water low in calcium. Conversely, hard water containing lots of calcium and magnesium is generally used for beers with darker taste profiles, maltier flavours, and rich mouthfeels. In fact, many regional beer styles developed due to the limitations imposed by the chemistry of the locally available water. For example, the very soft water of Pilsen, the home of Czech pilsner in contrast to the porters, stouts, and heavy larger like dunkels developed in cities like Dublin, Munich, and Dortmund, which are known for their hard water. Today, brewers can artificially control the chemical composition and pH of water, which allows them to brew any beer style, anywhere in the world.