# Technical Question T8: “Water” My Answer

Based off the length of an answer from Hommel. At about 400 characters. I’m trying a similar length(400 characters) with a similar depth of detail.

85-90% of your beer is water by volume. Learning and understanding basic water characteristics is where you go from a beginning brewer to an intermediate brewer. First and foremost you must rule out detectable metallic, pollutants and any smells or tastes that are off about the water. If necessary, get a test to detect these from a water company such as ward labs. Also be aware of city water supplies which may use chloramines and chlorine which will lead to the need for Campden tablets. Some brewers choose to use spring water, purified water or reverse osmosis water so they know 100% for sure what water they have. I choose to understand my home water profile and learn to work with it as I believe that’s true to how brewers historically dealt with water where they lived.

Once you understand your base water you then can consider the primary characteristics of “good” water and how to modify them for brewing. Primarily these are pH, Calcium, Chloride, Sulfates, Magnesium, Sodium and total hardness. Chlorides and Sulfates can impact the roundness of flavor or sharpness of bitter. Sodium aids in rounding out bitterness. For low bitterness, round beers, sulfates are usually less than 50 ppm. For bitter beers in the 150ppm range but not about 400ppm which can ruin a beer. Chlorides add a softness and roundness to malt flavors. It’s typically in the 50 to 100 ppm range. Calcium is important to the mash and to the yeast in their flocculation process, you will want minimum 50ppm in the finished wort. It is critically important to get your brewing water in the appropriate 5.2-5.6 pH range as pH will affect everything from enzyme function to yeast vitality to extraction of harsh tannins during the mash. Magnesium is necessary to tinker with unless your base water contains magnesium for reason.(it shouldn’t) In all grain you should get all the magnesium you need from the grain itself.

A pair of beer styles stand out in my mind in regards to how regional water impacted the history of beer. There are many but to an American these are the biggest.

First is the English pale ale style beer based on the Burton on Trent water profile. At one point in the 19th century Burton was responsible for 25% of Britain’s beer production largely because the water was so naturally high in sulfates to chloride ratio which is important in accenting the bitterness of the pale ales produced. This water is also high in total alkalinity making it naturally suitable for converting Munich and Vienna malts used in the style. The popularity of the bitter pale ales echoed in to the IPA revolution and led to the great IPAs we enjoy today.

Probably the largest impact of brewing water in regards to development of worldwide beer styles is that of Pilsen in the Czech Republic. The water is extremely pure with low levels of Calcium, Chlorides, Sulfate, Magnesium, Sodium and Carbonates. However, it is very low in alkalinity making it an excellent natural water for the conversion of lighter malts to produce a dry, crisp beer with great clarity and delicate round malt flavor. At a similar time as Burton on Trent, in the mid 19th centry, modern pilsner beer was invented here and spread like wildfire throughout Europe. Leading to the wonderful German, Czech and Bohemian beers we experience today. As well as the major beer brands of Heineken, Budweiser and Miller which dominate so much of today’s market.

References:

<http://www.brewerslair.com/index.php?p=brewhouse&d=water&id=&v=&term=1>

# Technical Question T8. “Water” From Tom’s Guide

#  Discuss the importance of water characteristics in the brewing process and how water has played a role in the development of at least four distinct world beer styles. Address the following topics:

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| **50%** | **Describe the importance of water characteristics in the brewing process.** |
| **50%** | **Describe the role in the development of beer styles.** |

Water constitutes 85-90% of beer by volume. It is unsuitable for brewing if: a) Detectable (i.e., testable) levels of metallic ions, b) High levels of pollutants, c) Smells and/or tastes bad for any other reason.

 Most city water supplies are suitable for brewing, but must remove chloramines (more rarely chlorine). If not removed, these compounds can complex into unpleasant-tasting chlorophenols during the fermentation process. High levels of chlorine compounds are also toxic to yeast. Well water can have high levels of metallic ions, dissolved salts (e.g., Ca++, SO4-) or organic contaminants (e.g., Nitrates).

 Boiling 30+ minutes will remove chlorine (but not chloramines). Adding potassium metabisulfite (Campden Tablet) and letting stand overnight will remove chloramines at a rate of 20 gallons per 50 mg sulfites (1 tablet). Charcoal filtration will remove both chlorine and chloramines, as well as metallic ions and some other contaminants (e.g., nitrates). Reverse Osmosis or distilled water will remove all contaminants and minerals. Ion exchange water softeners replace Ca++ ions with Na+ and are unacceptable for brewing.

 Water drawn from rocks which are mostly composed of silicon, like sandstone or granite, is generally soft, as is rainwater or surface water runoff. Water drawn from other types of rock, such as shale or limestone, is harder and is higher in levels of dissolved ions.

 **Hard vs. Soft Water:** Water with low levels of dissolved mineral salts (0-60 mg/l) is said to be “soft.” Water with higher levels (60-120 mg/l) is moderately hard, water with high levels (121-180 mg/l) is “hard” and water with higher levels (181+ mg/l) is very hard. About 85% of homes in the U.S. (esp. in the Midwest, South and Southwest) have moderately hard or harder water.

 **Temporary vs. Permanent Hardness:** Carbonate and bicarbonate compounds are responsible for temporary harness. Calcium, sulfate and chloride ions are responsible for permanent hardness. Temporary hardness refers to concentrations of mineral salts which can be precipitated out of solution by boiling or treatment with slaked lime. Permanent hardness refers to minerals which can’t be removed (except by distillation or ion-exchange filters).

 Total Hardness is the sum of both temporary and permanent hardness:

Total Hardness = Ca (ppm)/20 + Mg/12) x 50 = Total hardness CaCO3.

 **Total and Residual Alkalinity:** Pure water has pH 7 (on a 0-14 log scale for pH), while alkaline water can have up to pH 8. (By contrast, beer has pH Total Alkalinity refers to water’s ability to neutralize or buffer acids. It is roughly equivalent to carbonate alkalinity. , as measured by total plus permanent hardness. Alkalinity is mostly caused by Carbonates (CO3-) and Bicarbonates (HCO3-).

 In brewing, alkalinity acts as a buffer to mash pH, preventing the mash from falling into the required pH 5.2-5.8 (5.4 optimal) range and must be countered by additions of acid (e.g., 88% lactic acid USP, less commonly 38% Muriatic/Hydrochloric acid - HCl) or dark malt (reduces mash alkalinity by 0.1-0.2 pH). Historically, a phytic acid rest at 95 °F for 2 hours was also used for some styles. Acidulated malt (AKA Sauermaltz) can achieve the same effects as acid additions.

 Magnesium and calcium will reduce mash pH if added as salts which don’t contain carbonate or bicarbonate (e.g., CaCl, CaSO4, MgSO4), but these. For this reason, salts such as calcium chloride, magnesium sulfate (AKA Epsom salts) or calcium sulfate (gypsum) are sometimes used to adjust mash pH.

 Residual alkalinity (RA) refers to remaining alkalinity in the mash after malt phosphates complex with Ca++ and Mg+ ions in the mash.

Total Alkalinity = Ca (ppm)/3.5 + Mg (ppm)/7)

Residual Alkalinity = Temporary (Carbonate) Hardness - (Ca Hardness + 0.5 x Mg Hardness)/3.5.

 ***6. Salt Additions:*** The problem is that excessive levels of ions can impart unwanted characteristics to beer.

**D. Important Brewing Ions**

 Unless it has been distilled, water contains ions - positively or negatively charged atoms - from chemical compounds, usually salts, which have dissolved in the water.

 For brewing purposes, these are the most important ions:

 ***1. Metallic Ions:*** Iron (Fe+), Manganese (Mn+), Copper (Cu+), Zinc (Zn+). These are all necessary in trace amounts for yeast health. In excessive concentrations they can cause haze and produce metallic off-flavors. Metallic ions are generally present in sufficient levels in water that they don’t need to be added.

 ***2. Salts:*** These are simple water soluble chemical compounds consisting of a positively charged molecule or atom (a Cation) and a negatively charge molecule or atom (an Anion).

 **I. Cations:** Positively charged ions:

 **A. Calcium (Ca++):** The primary source of water hardness. Also described as temporary hardness. Reduces mash pH, 10-20 g/ml are needed for yeast nutrition. Calcium can be precipitated by boiling water and then letting it stand.

 ***B. Magnesium (Mg++):*** The next biggest source of water hardness. Also described as *permanent hardness* because it can’t be precipitated by boiling or lime treatments. It is an *important enzyme cofactor and yeast nutrient. At 10-30 mg/l it accentuates beer flavor.* At *higher levels* it imparts a harsh bitterness. At *125+ mg/l it is cathartic and diuretic.*

 **Sodium (Na+):** Imparts a sour, salty taste to beer. At 2-100 mg/l it accentuates beer sweetness. Higher levels are harsh-tasting and are poisonous to yeast.

 **II. Anions:** Negatively charged ions.

 **A. Carbonate/Bicarbonate (HCO3-, HCO3- -):** Sometimes expressed as alkalinity or temporary hardness. These compounds are strong alkaline buffer which raise mash pH and neutralize acids. They can contribute a harsh, bitter flavor to beer. Their alkaline effects are traditionally countered by brewing beers made with dark malts. Carbonates also help extract color from malt, giving darker colored beers.

 **B. Chloride (Cl-):** At 200-400 mg/l chloride accentuates sweetness, “mellowness” and perception of palate fullness. It also improves beer stability and improves clarity. Excessive levels can be bitter and salty.

 ***C. Sulfate (SO4- -):*** Also described as *permanent hardness* because it can’t be precipitated by boiling or lime treatments. Sulfate ions *impart dryness, fuller flavor and astringency* to beer. They also *aid alpha acid extraction* from hops and *increase the perception of hop bitterness.* These effects become more concentrated *at 200-400 mg/l. At levels above 500 mg/l sulfate becomes highly bitter.*

**E. Famous Brewing Waters**

 **Burton-on-Trent:** High total alkalinity and moderately high permanent hardness, with very high levels of calcium carbonate and calcium sulfate. This gave Burton beers a drier, fuller finish and accentuated hop bitterness.

 [In the early 19th century, the superiority of Burton water led to them taking much of the pale ale trade away from the London brewers. By about 1850, however, London brewers had learned to “Burtonize” their water, by adding mineral salts.] *Beer Styles:* English Pale Ale, IPA [Strong Ales].

 **Dortmund:** High total alkalinity and permanent hardness, with high sulfate and moderate carbonate levels. This accentuates hop bitterness and imparts “mineral” & sulfury hints. [Historically, Dortmunder export was developed in the 1890s, after brewers had a keen understanding of water treatment, so local water character probably didn’t play a big role in the emergence of the Dortmunder style. According to Jamil Zainasheff, Dortmunder brewers probably treated their water.] Beer Style: Dortmunder Export.

 **Dublin:** High total alkalinity, moderately high permanent hardness. Moderate levels of sulfates, very high levels of carbonates. Somewhat similar to London, so highly suited to brewing dark and amber beers. Beer Styles: Dry Stout [Porter, Irish Ale].

 ***Edinburgh:*** Medium carbonate water with medium calcium levels and low sulfate levels. Before Edinburgh brewers sunk wells in the 18th century, they might have used surface water which ran off from local peat bogs, which would have added “smoky” notes to their beer.

 [By the late 18th century Edinburgh brewers had access to both hard and soft water, sometimes within the same brewery, and could brew any style of beer they wanted. They were also major exporters of IPA and pale ales. The idea of commercial brewers using peaty surface water is nonsense since brewers of the period tried to avoid smoke flavors and surface water was likely to be badly polluted. But, “print the legend.”] *Beer Styles:* Scottish Ales, Scotch Ale. [And, actually, any style of ale. But, “print the legend.”]

 ***London:*** Medium to high total alkalinity and medium to high permanent hardness, with medium levels of sulfate and calcium. Well suited to producing dark, sweet beers. [Actually, there is no one profile for London water - it varies widely depending on the depth of the well, the location of the brewery, and in some cases, the flow of the tide up the Thames. Water drawn from the river itself is even more variable! Also, by about 1850, London brewers learned to treat their water by adding mineral salts. That said, the profile given above is fairly typical.] *Beer Style:* Brown Porter, [Sweet Stout, Southern English Brown, Pale ales].

 ***Munich:*** *High total alkalinity and moderately high permanent hardness.* It also has *high levels of sulfates.* [Historically, Munich brewers learned to adjust their water chemistry about the same time that everyone else did. Since most Munich beer styles emerged in their modern form after 1850, water character probably didn’t have much to do with the development of modern Munich beers. It’s also odd that despite the high sulfate water, most Munich styles are malty!] *Beer Style:* Munich Dunkel [Dark and amber lagers, Bocks].

 **Plzen:** Extremely soft water, with very low total alkalinity, and low overall ion levels. As close to pure water as ground water gets. Lack of ions decreases perception of hop bitterness, and historically made acid rests and decoction mashing necessary due to lack of minerals to aid enzymatic reactions in the mash. Beer Style: Bohemian Pilsner.

 **Vienna:** High total alkalinity and moderately high permanent hardness. High in calcium and medium high in carbonates. Somewhat similar to London or Dublin. Suited to amber or dark, sweet beers. Beer Style: Vienna Lager [Amber Lager].

# **Question T8 “Water” Sample Answer**

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| Treatment | Effects |
| Boiling | Removes chlorine, kills bacteria |
| Charcoal Filtration | Removes chlorine, chloramines & metallic ions. |
| Campden Tablets | 1 tablet/20 gal. H20, converts chloramines to volatile chlorides & sulfites w/in 15 minutes. |
| Reverse Osmosis | Removes most bacteria, chlorine, chloramines and ions. 100% r/o water not recommended – insufficient minerals for yeast development/mash enzyme action. |

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| Important Ions | Level (ppm) | Effect |
| Iron (Fe), Manganese (Mg), Copper (Cu), Zinc (Zn) | trace | Necc. in trace amounts for yeast health. Excessive (i.e., detectable) lvls. = haze, metallic off-flavors. |
| Salts - Cations |  |  |
| Calcium (Ca++) | 50-150 | Primary source of permanent hardness. Reduces mash pH, Aids beer clarity, flavor and stability. 10-20 ppm needed for yeast nutrition, 50 ppm needed for proper mash enyzme, boil reactions. |
| Magnesium (Mg++) | 10-30 | Second. source of perm hardness. Enzyme cofactor & yeast nutrient. Accentuates flavor @ 10 -30 ppm. >50 = harsh bitterness. >125 ppm = laxative & diuretic. |
| Sodium (Na+) | 0-150 | Gives salty and sour taste. 70-100 ppm accentuates sweetness 200+ = salty, harsh bitter w/ SO4, poisonous to yeast. |
| Salt - Anions |  |  |
| Bicarbonate/Carbonate (CO3, HCO3-) | 0-250 | Main source of Temp. Hardness and Total Alkalinity. Strong alkaline buffer - raises mash pH, neutralizes acids. Contributes harsh, bitter flavor. Alkaline effects trad. countered by using dark malt. 0-50 ppm for pale beers, 50-150 for amber/brown, 150-250 for dark, roasted beers. |
| Chloride (Cl-) | 0-250 | Accentuates sweetness, “mellowness” & perception of palate fullness. Improves stability & clarity. >300 ppm = chlorophenols. |
| Sulfate (SO4-) | 0-350 | Part of perm. hardness. Accentuates hop bitter. Prod. dry, fuller flavor. 0-50 ppm for malt-focused, 50-150 for normal, 150-350 for very bitter beers. Some sharpness. >400= v. harsh bitter > 750 ppm = laxative. |

**pH (Power of Hydrogen):** Pure water/neutral = pH 7. Acidic = 0-6 (e.g., Beer ~3.2-3.8), Alkaline = 8-14.

**Proper mash pH** = 5.2 - 5.8 pH. > 5.8 pH = Polyphenol/tannin & silicate extraction. < 5.2. pH = Enzyme probs. Mash pH drops naturally due to reax. of phosphates in malt & Ca++ and Mg+ions.

**Total Alkalinity** = Temporary - Perm. Hardness.

Residual Alkalinity = Remaining alkalinity in mash after malt (phosphate & Ca++ or Mg++ reax.) and acid additions. High carbonate H2O or adding carbonates increases RA, adding acids (e.g., 88% USP Lactic), Ca++, Mg++ (as CaCl, MgSO4 or MgCl) reduces it.

**Acids used to adjust pH:** Lactic acid, sulfuric acid (used by commercial breweries for cost reasons). Phosphoric can mess with calcium levels, so not recommended. Acidulated malt (sauermaltz) = sour-mashed and dried malt, or sour mash (base malt inoculated with Lactobacillus Delbruckii & held at 120 °F for 1-3 days) used for Reinheitsgebot-compliant breweries. Must be careful w. pH adjustments to avoid imparting sourness & getting mash pH too low. More necc. w. alkaline H2O or mash using just pale malts.

**Acid Rest:** ~95 °F for up to 2 h. Tradit. Used for Bohem. Pils. Convert phytins in malt to phytic acid in undermodified light malts. Not necc. w. modern malts.

**Famous Brewing Waters**

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| City | Beer Style | Water Effects |
| Burton-on-Trent | Eng. IPA | Extremely hard, high CaSO4e & HCO3- lvl. Dives dry, fuller finish & accentuates hop bitter. |
| Dortmund | Dort. Export | High SO4-, med. HCO3. Accentuates hop bitter. Gives “mineral” & sulfur hints. |
| Dublin | Dry Stout | High Ca++ & HCO3. Balances acidifying effect of dark malts. |
| Edinburgh | Scottish Ale | Med. HCO3. Surface water running through peat bogs “historically” added “smoky” notes, accentuated by yeast strain & lower ferment. temp. |
| London | Brown Porter | High alkaline & carbonate water balances acidifying effect of dark malts, extracts color. |
| Munich | Munich Dunkel | High alkaline & carbonate water balances acidifying effect of dark malts, extracts color. |
| Plzen | Boh. Pilsner | Extrem. soft H20, w/ v. low dissolved ions. Decrease. hop bitter. Acid rest & decoction mash trad. necc. due to lack of minerals to aid enzymatic reax. in mash. |
| Vienna | Vienna Lager | Hard, carbonate-rich water extracts the color from Vienna malt. |