2017 ASBC Annual Meeting
June 4–7 ■ Fort Myers, Florida
See what SCIENCE can brew for you

Water

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Molson Coors

Contents

Introduction

Water…..

- Comprises over 90% of beer (90-96%)
- Process water: ingredient or product-contact surfaces
  - Grain foundation and sparge water
  - Dilution
  - Sanitation and rinsing of vessels, pipes and filters
  - Line packing and beer chasing
  - Yeast washing
  - Bottle/can/keg rinsing and bottle jetters
  - Carbon dioxide reclaiming and scrubbing

- Its condition can affect the quality of the beer
- Composition directly or indirectly effects flavor/aroma/taste, microbiological & physical stability, pH, saccharification, turbidity, filterability/viscosity, hot/cold break, color, oxalate removal, yeast health, fermentation, flocculation….

Introduction

Water…..

- Availability and suitability were traditionally a Brewer’s guide to the location of the brewery
- Has its own unique taste and differs from city to city and country to country
- Sources include
  - Surface waters: rivers, lakes and reservoirs
    - Low mineral and high organic (biologically active)
  - Ground water: shallow or deep wells
    - High mineral and low organic

Desirable Characteristics

Water used in brewing shall be

- Free from micro-organisms
- Colorless and clear
- Tasteless and odorless
- Near neutral pH, at least a pH 7.0
- Meet regulatory potable water standards

Water Hardness

- Is a measure of calcium and magnesium levels
  - Examples: $Ca(CO_3)$, $CaCl_2$, $Mg(CO_3)$, $MgCl_2$
- There are different degrees of hardness (expressed as $CaCO_3$)

Types of Water	Ranges
Soft	0 – 50 ppm
Moderately Soft	50 – 100 ppm
Slightly Hard	100 – 200 ppm
Moderately Hard	200 – 300 ppm
Hard	300 – 450 ppm
Very Hard	> 450 ppm

Water Hardness

- Causes limestone scaling which leads to reduced heat transfer efficiencies
- Causes the minerals in solutions to adjust wort pH leading to altered wort composition and fermentation performance
- Exists in two forms
    - Temporary hardness
    - Permanent hardness

Water Hardness

Temporary Hardness (carbonate)…

- Ca^{++} and Mg^{++} salts of bicarbonates
- Generally raises the pH of the water
- Can be removed by boiling, converting soluble bicarbonates to insoluble CaCO3 & Mg(OH)2

$$Ca(HCO_3)_2 \xrightarrow{\Delta} CaCO_3\downarrow + H_2O + CO_2\uparrow$$

$$Mg(HCO_3)_2 \xrightarrow{\Delta} MgCO_3 + H_2O + CO_2 \xrightarrow{\Delta} Mg(OH)_2\downarrow + 2CO_2\uparrow$$

- These carbonates coat the heating vessel
- The insoluble carbonates can be easily removed by filtration

Water Hardness

Permanent Hardness (non-carbonate)…

- Ca^{++} & Mg^{++} salts of sulfates and chlorides
- Tends to lower the pH of the water
- Their concentrations are not influenced by boiling
- Removal of the "permanent hardness" salts is a more involved operation, usually involving alterations to the pH and ion balance within the water

Temporary Hardness + Permanent Hardness = Total Hardness

Alkalinity

- Is a measure of the buffering capacity of bicarbonate ($HCO3^{-}$), carbonate ($CO3^{=}$) and hydroxide (OH^{-}) anions expressed in terms of ppm CaCO3
- The quantitative capacity of water to neutralize an acid
- Is expressed in mg/L of equivalent calcium carbonate
- Is > hardness, then the water hardness is mostly temporary
- Is < hardness the difference indicates permanent sulfate hardness
- Is higher in ground water (wells)
- Is lower in surface water (rivers and streams)

Alkalinity

- Is a calculated expression of the carbonate (CO_3) and bicarbonate (HCO_3) levels of $CaCO_3$, $MgCO_3$, $NaHCO_3$.
- Ranges of calculated alkalinity from bicarbonate as $CaCO_3$

Ranges	Beer and Malt Types
0 – 80 ppm	Pale beers with lightly kilned malts
80 – 250 ppm	Amber colored beers with toasted malts
250 – 400 ppm	Dark beers with roasted malts

- Alkalinity is neutralized by:
  - The addition of acid
  - Darker roasted malts (higher acidity)

Residual Alkalinity

- Residual Alkalinity (RA) is the difference between temporary (carbonate) hardness and permanent (non-carbonate) hardness
- The excess alkalinity that is not neutralized by the reaction between calcium and magnesium with phosphates in the mash
  - Paul Kohlbach formula
    - RA = Total Alkalinity – (Ca/3.5 +Mg/7), expressed as ppm $CaCO_3$

Residual Alkalinity	Description	Descriptor
Positive	Excess of carbonate present	More basic
Negative	Excess of Ca^{++} and Mg^{++} ions	More acidic

- The net effect of hardness, alkalinity, and the material bill determine the mash pH

pH

- Is the availability of hydrogen ions in water
- Range in water – 6.5 – 8.4
- Is a function of temperature
  - As temperature increases, pH drops
- Enzymes that break down starches work best over a Mash pH range of 5.2 – 5.5
- Mash pH influences:
  - Starch conversion
  - Enzyme activity
  - Clarity

Brewing Water Mineral/Ion Content

Ions	Brewing Range	Effects	Adverse Effects
Calcium (Ca^{++})	50 – 150 ppm	• Contributes to hardness • Lowers mash/wort pH • Protects a-amylase from thermal degradation, increases β-amylase activity • Precipitates oxalate anion as insoluble calcium oxalate • Improves yeast growth and flocculation • Improves extract recovery • **Produces a clean, dry taste**	• Reduces mash pH • Negatively impacts upon hop utilization.
Magnesium (Mg^{++})	0 – 30 ppm	• Contributes to hardness • Mg^{++} salts are more soluble than Ca^{++} and have similar effects but to a lesser degree • Acts as an enzyme co-factor in yeast	• **Gives a sour, slightly bitter taste > 15-20 ppm** • **Gives as astringent mouthfeel >15 ppm** • In excess, has a laxative effect and may increase wort pH

Brewing Water Mineral/Ion Content

Ions	Brewing Range	Effects	Adverse Effects
Sodium (Na^+)	0 – 150 ppm	• As a bicarbonate salt, raises water alkalinity and wort pH • **At low levels imparts a slight sweetness** • **Between 75-100 ppm accentuates malty flavors and palate fullness**	• **Imparts a sour and salty flavor between 75-100 ppm** • **In excess, produces a harsh taste** and is toxic to yeast
Potassium (K^+)	0 – 10 ppm	• As a bicarbonate salt, raises water alkalinity and wort pH • Similar to Mg^{++}, required at trace levels as a yeast co-factor (adsorption of phosphate)	• **Salty characteristic similar to sodium, without the sour notes** • Inhibits certain mash enzymes > 15 ppm • In excess, has a laxative effect

Brewing Water Mineral/Ion Content

Ions	Brewing Range	Effects	Adverse Effects
Copper Cu^{++}	0.5 ppm	• Not usually a desirable mineral • Essential yeast trace metal at <0.6 ppm • **Reacts with sulfides to reduce sulfidic flavors**	• Inhibits yeast growth > 0.6 ppm and is toxic > 10 ppm • Catalyst in auto-oxidation of polyphenols • Produces irreversible hazes and product **oxidation** from dilution water • Accelerates corrosion/oxidation of vessels, piping, weld points
Iron, Fe^{++}, Fe^{+++}		• Essential yeast trace metal at <0.1 ppm	• Reduces saccharification at levels >0.1 ppm and produces protein-tannin hazes • Toxic to yeast >0.5 ppm • Catalyst in auto-oxidation of polyphenols • Produces irreversible hazes and product oxidation from dilution water • Corrosion/oxidation of vessels, piping, weld points • **Metallic off taste**

Brewing Water Mineral/Ion Content

Ions	Brewing Range	Effects	Adverse Effects
Zinc (Zn^{++})	0.5 ppm	• Yeast nutrient • Co-enzyme for normal yeast metabolism	• Above 0.2 ppm can inhibit saccharification and produce haze • Above 1.0 ppm can inhibit yeast growth • Toxic to yeast above 5 ppm • **As a transition metal, high levels in dilution water may contribute to oxidation**
Chloride Cl-	0 - 250 ppm	• Improves clarification and colloidal stability • **Increases palate fullness** • **Provides a mellow flavor**	• In excess, inhibits protease activity, yeast flocculation and fermentation
Sulfate SO4-	50 – 150 ppm	• With Ca++, lowers wort pH • Source of sulphur for yeast • **Complexes with magnesium impart drier flavors** • **Accentuates bitterness**	• Affects protease activity • **Enhances astringency**

Microbial Contaminants

- Negatively impact food (beer) safety, beer stability and fermentation performance efficiency
- Are not likely to be present during brewhouse operations of mashing and boiling (sufficient to combat microbial threats)
- May be present in dilution water and CIP final rinse water as this water source may not follow the same treatment as brewing liquor

Microbial Contaminants

United States Environmental Protection Agency (EPA) - Microbial Drinking Water Maximum Contaminant Limits (MCLs)

Contaminant		Sources of Contaminant
Cryptosporidium	0	Human and animal fecal waste
Giardia lamblia	0	Human and animal fecal waste
Legionella	0	Found naturally in water; multiplies in heating systems
Viruses (enteric)		Human and animal fecal waste
Heterotrophic Plate Count (measures a range of bacteria)	N/A	Naturally present in the environment
Total Coliform Bacteria (Including fecal coliform and E. coli)	0	Coliforms are naturally present in: • Environment • Feces • Fecal coliforms • E. coli (from human and animal fecal waste)
Turbidity	N/A	Soil runoff

http://water.epa.gov/drink/contaminants/index.cfm

Water Treatment Processes

Treatment	Description	Advantages and Disadvantages
Chlorine	Reacts with water to form hypochlorous acid (HOCl) and hydrochloric acid (HCL) or hypochorite (OCL) and chloride (Cl) depending on the water pH	• Strong disinfecting capability • Low cost • Interacts with wort to produce chlorophenols
Chloramination	Uses chlorine and ammonia	• "Swimming pool" odor, low sensory threshold • Chloramines do not react with dissolved organics to form THM's, or with phenols to produce chlorophenols and medicinal aromas in beet
Chlorine Dioxide	Is a powerful disinfectant and oxidizing agent	• Does not form chlorophenols or other organic halogens • Effective against a broad spectrum of microorganisms
Reverse Osmosis	Removes about 94% of the ions from water	• Minerals are added based on beer style
Ultra-violet	Ultraviolet light in the range 200-280 nm destroys the DNA in microbial contaminants	• No residual action after application • Highly colored water with a high level of turbidity will restrict sterilization
Ozone	Is produced by passing a flow of air or oxygen through a high voltage field in which the reaction $3O_2 \rightarrow 2O_3$ proceeds	• Strong disinfecting effect • Ozone reacts with organic matter and may require removal of organics by pre-carbon treatment • Does not form THMs
Carbon Filtration	Uses a bed of activated carbon to remove contaminants and impurities, using chemical adsorption	• Effective at removing volatile organic compounds • Not effective at removing inorganic compounds

Watermelon

Earthy

Salty

Musty

Fishy

Common Off-Flavors in Water

Chlorine

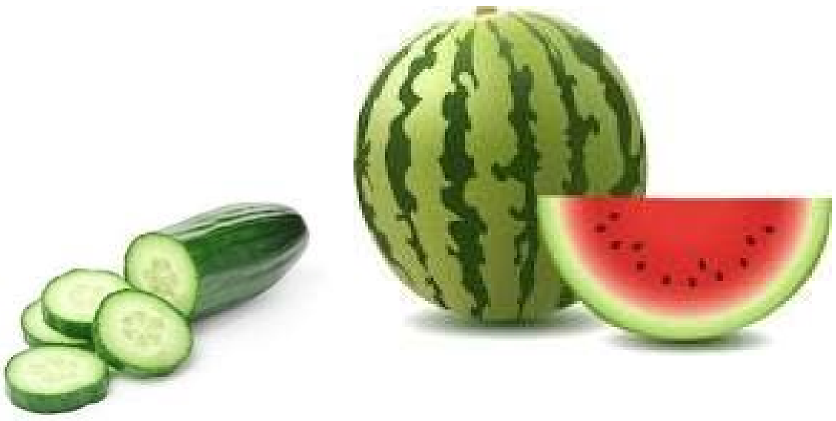
Moldy

Metallic

Medicinal

Sulfury

Tasting: Nonadienal



- Described as:
  - Cucumber
  - Watermelon
- Compound:
  - *trans*,*cis*-2,6-nonadienal
- Origin:
  - Algae bloom from surface water sources such as lakes, rivers or reservoirs; produced by actively growing organisms and as a result of cell lysis

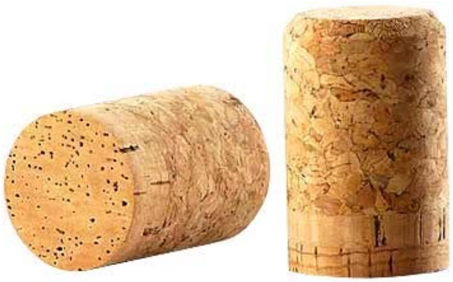
Tasting: Geosmin

- Described as:
  - Earthy
  - Damp soil
  - Sugar beet-like
- Compound:
  - Geosmin
- Origin:
  - Common flavor problem found with potable water. Formed by bacteria and algae in lakes, reservoirs or distribution systems. Produced by active microorganisms and decomposition of dead cells.

Tasting: Dimethyl Disulphide

- Described as:
  - Rotten vegetables
  - Sewage treatment plant
- Compound:
  - Dimethyl disulphide
- Origin
  - Biochemical decay of grass and vegetation in reservoirs and lakes or by metabolism of bacteria and molds

Tasting: Musty



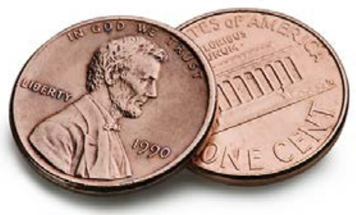
- Described as:
  - Musty
  - Corked wine
  - Cellar-like
- Compound:
  - 2,4,6 tribromoanisole
- Origin:
  - Produced by molds or actinobacteria in water distribution systems

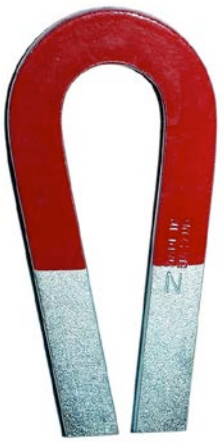
Tasting: Chlorophenol

- Described as:
  - Medicinal
  - Antiseptic
- Compound:
  - 2,6-dichlorophenol
- Origin:
  - Produced in water by reactions with phenolic compounds (such as peaty soils) and chlorine. Also can be produced by misuse of carbon filters used to purify water and remove chlorine.

Tasting: Metallic

- Described as:
  - Metallic
  - Inky
  - Blood-like
- Compound:
  - Ferrous sulfate
- Origin:
  - Ferrous compounds are naturally found in some water supplies from natural ground and soil conditions. Also from corrosion of pipes.





Beer Styles and Water

- Water is one of the essential ingredients in beer
- The balance of minerals in the brewing water will:
  - Affect flavor character and flavor perception of:
    - Malt
    - Hops
    - By-products of fermentation
- The balance of minerals in the brewing water will influence:
  - Performance of yeast
  - Beer flavor
  - Beer aroma
  - Beer mouthfeel

Classic Brewing Waters

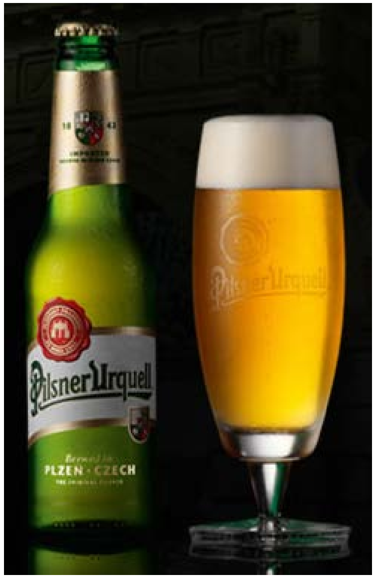
Brewing Regions	Style of Beers	Ca+2	Mg+2	Na+1	Cl-1	SO2+2	HCO3-1	Hardness (Total)
Pilzen	• Light coloured • Hoppy	7	2	2	5	5	15	30
Burton-on-Trent	• Amber pale ales • Sulphate hoppy character	295	45	55	25	725	300	850
Dublin	Dark malty ales Medium bitterness	115	4	12	19	55	200	300
Tadcaster	Ales and stouts	35	5	28	52	87	16	110
Dortmund	Strong, hoppy pale/amber lagers Malty palate	250	25	70	100	280	550	750
Munich	Dark, malty lagers	75	20	10	2	10	200	250

Note: units ppm

How To Evaluate Beer…….

- Pour into a beer clean glass
- Look at the appearance of the beer
  - Note color, clarity and foam
- Swirl the beer to generate foam
- Bring glass up to nose and take two short sniffs then a long sniff
  - Note aroma
- Take a sip of beer and let it move across your tongue for a few seconds
  - Note aromatics, tastes, mouthfeels
- Swallow the beer
  - Note finish

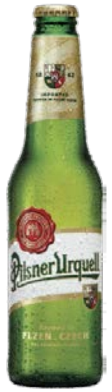
Pilsner Urquell



Pilsner Urquell

- Pilzen water is very soft with low concentrations of dissolved ions
- Decoction mashing is common in Plzen
  - The decoction process allows enzymes to work even though the calcium levels are very low.
- Pilsner is a bottom-fermented beer
- Pilsner Urquell is produced with
  - Locally grown malted 2-row barley from Bohemia and nearby Moravia
  - Saaz aroma hops
  - Triple decoction mashing process

Pilsner Urquell



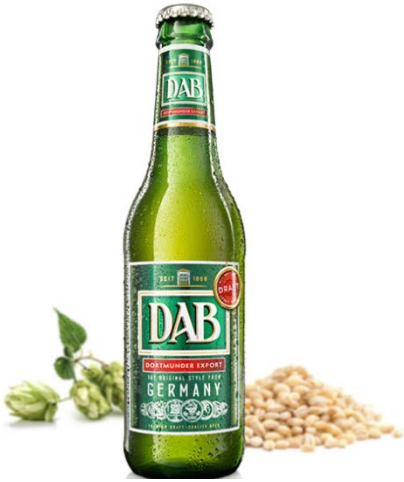
Beer Style : Pilsner

- 36 BU's
- 4.5 % ABV

Sensory Characteristics

Appearance:	Deep gold color with a dense creamy white foam
Aroma:	Spicy, floral hop aroma with a hint of caramel, buttery aroma
Taste:	Pronounced hop flavor with a complex maltiness, strong bitterness and an assertive acidity
Mouthfeel:	Full body, slightly drying
Finish:	Soft bitterness that does not linger

Dortmunder Export



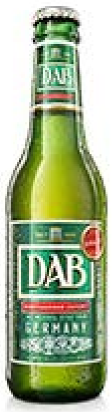
DAB Export

- Brewed in Dortmunder, Germany with Noble Hops and Pilsner Malt
- Produced from waters which are:
  - High in total hardness
  - Fairly high in sulfates (giving it a sulfury aroma)
  - High chlorides (increasing palate fullness)
  - High in carbonates (giving it a slight sharpness to the hops)

DAB Export

Beer Style: Dortmunder Export

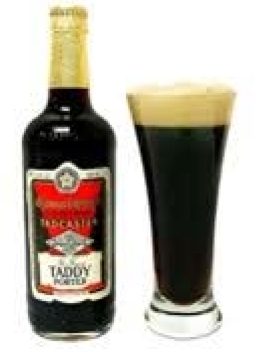
- 22 IBU's
- 5.0% ABV



Sensory Characteristics

Appearance:	Golden color, creamy foam
Aroma:	Noble hop aroma with a malty/biscuity character and a slight sulfury note
Taste:	Malty with a medium hop flavor, moderate bitterness and slight sweetness
Mouthfeel:	Full body and crisp
Finish:	Malty finish

Samuel Smith's Taddy Porter



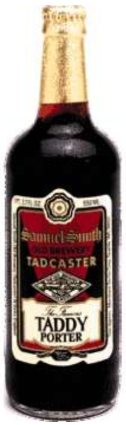
Samuel Smith’s Taddy Porter

- The brewing water is drawn from 85 feet underground from the original well from Sam Smith’s Old Brewery sunk in 1758 and is synonymous with classic English hard water.
- Produced with
  - Pale and roasted malts
  - Fuggles and Goldings hops
- The malt mixes with hard well water in copper mash-tuns.
  - High level of bicarbonates neutralizes acids in dark malts

Sam’s Smith Taddy Porter

Beer Style: Porter

- 32 BU’s
- 5% ABV



Sensory Characteristics

Appearance:	Dark brown/black color, creamy tan foam
Aroma:	Malty aroma with toasted/roasted notes of chocolate, coffee and slight smoky
Taste:	Sweet malty flavor with caramel and roasted notes, a slight acidity and a strong bitterness
Mouthfeel:	Full body
Finish:	Astringent with a lingering roasted finish

Questions