W.O.W. – Waters of the World

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First things smirst

- ~95% beer is aqua
- Styles developed b/c of the water of the city
Types-O-Aqua

- Tap water
- Spring water
- RO water
- Distilled water
- ‘Heavy’ water
  - Deuterium isotope – good for things like the Manhattan project NOT brewing
Distilled Water

1. Contaminated water
2. Heat from the heating element
3. Evaporation of $H_2O$ molecules
4. Condenser
5. Cool air from fan
6. Distilled water
7. Distilled water storage
A method of producing pure water by forcing saline or impure water through a semipermeable membrane across which salts or impurities cannot pass.
RO – Under counter

- **Stage 1 - Sediment Prefiltration** - 1 micron cartridge that traps dirt, rust, mud, hair

- **Stage 2 - Chlorine Prefiltration** - 1 micron chemical removal cartridge to ensure no chemical deterioration of membrane from residual chlorine.

- **Stage 3 - Membrane Process**
  This is the primary component that can separate up to 98% of dissolved metals and minerals from ordinary tap water.
RO - Membrane pore size

Yeast 5-12u
Spring Water

- Spring water is water that comes out of the ground on its own or is bottled near water that comes out of the ground on its own.

- Check ion content
Tap Water – The Bad

- ‘Bad’
  - Non-potable
  - Chlorine and/or Chloramines
  - Sulfur
  - Nitrates – ummm...poop
  - Corn chips, old feet, etc
Chlorine, borine!!!

- Chlorine gas
  - Used VERY little
  - Boils off easily

- Chloramines
  - Used most often
  - Need carbon filter to remove
    - Sulfate and UV bs
  - Boil only concentrates!!
Nitrates = POO!

Increasing risk of ground-water contamination

<table>
<thead>
<tr>
<th>Nitrogen Input</th>
<th>Aquifer Vulnerability</th>
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<tr>
<td>High</td>
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Tap Water – The Good

- **Good**
  - Anything you can drink - potable water
  - Well water
  - NOT through ‘softener’
  - Carbon filtered
    - Removes Cl and other nasty stuff
Activated Carbon

- **Uses**
  - Air purification
  - Water purification
  - Booze purification
  - Hospital

*Figure 1. Schematic representation of formation of Water-Soluble Active Carbon from carbon black.*
Activated Carbon

- Charcoal that has been treated with **oxygen**
- 300-2,000 m²/g (3200-21500 ft²/g)
  - A tennis court is about 260 m² (2800ft²/g)
- Trap
  - Carbon-based contaminants – flavor and odorous stuff
  - Chlorine
- Pass
  - Sodium, Nitrates
- Good at trapping other carbon-based impurities ("organic" chemicals), as well as things like chlorine.
- Once all of the bonding sites are filled, an activated charcoal filter stops working.
Ummm….honeycomb!
Chemistry Primer
Atoms

- Atoms are composed of protons, neutrons, and electrons.

- **Protons** and **neutrons** are located in a central area called the nucleus.

- **Electrons** move about the nucleus. The number of electrons is equal to the number of protons.
  - Electrons in cloud, not ring
Periodic Table of the Elements

The Atomic Masses in parentheses are those of the most stable or common isotope.
Compounds

- Elements cannot be broken down into substances with different properties.

- Substances that are composed of two or more elements are called **compounds**.

- For example, water (H2O) is not an element because it can be broken down into hydrogen (H) and oxygen (O).
Ionic bonding is the transfer of electrons from one atom to another. Atoms that have lost or gained electrons are called ions.

- + = Cations
- - = Anions
Ionization
H-Deuce-O

- Polar
- Covalent
  - Shares electrons, doesn't lose or gain
- Molecule
Big prop’s

- Solvent
- High surface tension
- ‘Water bugs’
- Action is independent of volume
Sorry, its not that simple...

- Review
  - Water types
  - Water properties
  - Solutes – bits in the water
Cations – Positive

- Most widely occurring cations in water
  - Ca >> Mg > Na >> K >> Mn

- Ca
  - *Principle mineral hardness*
  - ↓ mash pH, enzyme activity, protein digestion, lauter runoff
  - Neutralizes toxic substances in yeast: Peptone & Lecithin
  - Inverts malt phosphate to pp alkaline phosphate

- Mg
  - 2ndary mineral in hardness
  - Accentuates bitterness

- Na
  - Accentuates beer flavor
Anions - Negative

- **CO$_3^{2-}$** - Carbonate
  - *Contributes most of alkalinity*
  - **CO$_3^{2-}$ + H$_2$O → HCO$_3^{-}$ + OH$^-$**
    - Pulls H$^+$ from H$_2$O = OH$^-$
    - STRONG alkaline buffer = neutralizes acids
      - Resists ↓ mash pH
      - ↓ α-amylase activity, cold break,
    - >200ppm = NEEDED dark roast grains to buffer

- **SO$_4^{2-}$** - Sulfate
  - Weak buffer
  - >150ppm = cleaner, more pleasant bitter

- **Cl$^-$** - Chloride
  - Very weak buffer
Complicated??

- Ca $\rightarrow$ mash pH

- CO3 – buffers mash pH
  - resists changes in mash pH
  - neutralizes acid
Hard vs Soft: The other definition

- Old Skizool nomenclature: Ability to form a lather with a bar of soap??
  - Hard: Buncha stuff
  - Soft: notta so much stuff
Water Softener

- Exchanges Na for Ca and Mg
  - Ca/ Mg precipitate out in pipes
  - ‘Scale’ or ‘Beer Stone’

- Bypass!!!
**Hardness**

- **Ca & Mg in water**
  - Inhibit lather of soap = "hard"
  - Slightly acidic = weak bonds
  - Combine with CO$_3^{2-}$, SO$_4^{2-}$
    - PP as insoluble mineral salts

- **Temporary vs. Permanent**
  - Temp = carbonate hardness
    - part of hardness that will disappear after boiling
  - Permanent
    - Ca/Mg with non-carbonate ions

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**CaCO$_3$ Hardness**

Soft 50ppm → Hard 300ppm
Alkalinity

- buffering capacity of dissolved anions
- $\text{HCO}_3^- \ (\text{bicarbonate}) \sim \text{CO}_3^{2-} \rightarrow \text{ONLY significant factor}$
Accepted standard – CaCO₃

- expresses hardness and alkalinity together
- Ca – primary mineral of hardness
- CO₃ – principle cause of alkalinity
Alkalinity > hardness → hardness is **TEMPORARY**

Hardness > alkalinity → **PERMANENT**

SO4 hardness
**pH**

- Measure of acid (H+) to alkaline (OH-) ratios of a solution

- pH values run from 1 to 14
  - negative log10 of [H+]
  - 0 (highly acidic) to 14 (highly basic), 7 neutral
Das pH boot camp

- Log scale
  - pH = \(-\log_{10} [H^+]\)
  - By 10’s
  - Calculation
    - Change pH from 7 to 5
    - \(10^{-7} \rightarrow 10^{-6} \rightarrow 10^{-5}\)
      - \(10^2 = 10 \times 10 = \text{increase} [H^+] = 100 \text{ fold}\)

- HCl(aq) \([H^+] = 0.01 = \text{pH}2\)
- Distilled H2O(l) \([H^+] = 0.0000001 = \text{pH}7\)
- NaOH(aq) \([H^+] = 0.00000000000001 = \text{pH}14\)

- The more acidic the solution, the lower the pH value;

- Conversely: the pH value rises as the solution becomes more alkaline.
pH in Brewing

- **pH in Brewing**

- prerequisite of brewing cycle!!
  - Enzyme activity, kettle break, yeast performance, hop extraction, clarification (flocculation)

- **Target pH**
  - pH 5.2 – 5.5 = saccrification
  - pH 5.0 = protein degradation
  - pH 5.5 = amylase
  - pH 6.0 = reduce enzymatic activities, extracts, tannins
Malt pH

- Distilled H2O = NO ions
  - 100% base = pH 5.7 - 5.8
  - Caramel/crystal = pH 4.5 – 4.8
  - Chocolate = pH 4.3 – 4.5
  - Black/RB = pH 4.0 – 4.2
Water Treatment

- ↓ pH = MOST common
- ↓ HCO₃??
  - Boil
    - PP out organic salts in boil
    - CO₂ + H₂O = H₂CO₃
    - H₂CO₃ ⇌ HCO₃⁻ + H⁺
  - Roast malts
    - Acid is created over high kiln temperatures
  - Dublin
- Add acid
  - Phosphoric acid
    - H₃PO₄ + CaCO₃ → H₂CO₃ + CaHPO₄ pp
  - Lactic acid
    - 2C₃H₆O₃ + CaCO₃ → H₂CO₃ + Ca(C₃H₅O₃)₂ pp
Summarization

- IMPORTANTANTE!!!!
- Types aqua
- Chemistry
- Ions
- pH
  - Adjustments
Transmogrification

- Brewing centers
- Specific water
- Salt Additions
- Recreations!!
Brewing Capitals
How much do you know???
# Beer central

<table>
<thead>
<tr>
<th></th>
<th>Beer Central</th>
<th>Details</th>
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<tbody>
<tr>
<td>1.</td>
<td>Pilsen</td>
<td>Softest brewing water – pale and clean beers</td>
</tr>
<tr>
<td>2.</td>
<td>Munich</td>
<td>High Carbonates – low hops, high color and malt</td>
</tr>
<tr>
<td>3.</td>
<td>London</td>
<td>High Carbonates – smooth dark ales</td>
</tr>
<tr>
<td>4.</td>
<td>Dublin</td>
<td>VERY VERY high Carbonate levels – acidic dark malts needed for mash pH</td>
</tr>
<tr>
<td>5.</td>
<td>Edinburgh</td>
<td>similar to London's, more bicarbonate and sulfate, lends heavier malt body</td>
</tr>
</tbody>
</table>
Rock Formations

- **Non-reactive**
  - Granite, Sandstone
    - \(~90\%\) Silica (SiO\(_2\))

- **Reactive**
  - Lime Stone (CaCO\(_3\))
  - Dolomite (CaMg(CO\(_3\))\(_2\))
  - Gypsum (CaSO\(_4\))
Specific locations

- Marston's Field Well
- Marston's Brewery
- Burton upon Trent
- River Trent

CaSO$_4$

Keuper Marl Gypsum

Lower Keuper

Pebble Bed With Sandstone
Blessed waters

- Brewing city, check! ...specific water???
Water Salts: Stick the what in the where now??

<table>
<thead>
<tr>
<th></th>
<th>Pilsen</th>
<th>Munich</th>
<th>London</th>
<th>Vienna</th>
<th>Dublin</th>
<th>Dortmund</th>
<th>Burton</th>
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<td>319</td>
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</table>

10gal Salts
Exact!?

- Only worry is solubility!
- Don’t have to be exactly accurate
- Mother Nature
  - Not same stuff we have
Stick the what in the where now??

**Key ideas**

- WEIGH, WEIGH, WEIGHT - DON’T use volumes e.g. NO tsp
- Add to water then to mash, NOT directly

- **CaCO3 – Calcium carbonate (chalk)**
  - Buffers mash acidity
  - Partly pp in kettle

- **CaSO4 – Gypsum**
  - ↓ pH = pp CaPO4

- **MgSO4 – Epsom salts**
  - ↑ Mg & SO4

- **Ca(OH)2 – Slaked lime**
  - ↑ pH = pp CaCO3
Tasting!!!

- Taste the water
  - Get a ‘feel’ for it
  - Slosh it around
- Sip distilled water for rinse
- Taste the beer
  - Think about the ‘flavor’, mouthfeel
- Repeat
- Compare the water with the beer
Order

1. Edinburgh
   1. Balhaven Scottish
2. Köln
   1. Reissdorf kölsch
3. Munich
   1. Hacker-Pschorr Ofest
4. London
   1. Fullers London Pride
5. Plzeň
   1. Pilsner Urquell
6. Dublin
   1. Guinness
# Water Analysis

<table>
<thead>
<tr>
<th>SOURCE</th>
<th>Ca</th>
<th>Mg</th>
<th>Na</th>
<th>CO3</th>
<th>SO4</th>
<th>Cl</th>
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