The Importance of Water and Water Quality in Brewing

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You can't have a Real Country unless you have a BEER and an airline - it helps if you have some kind of a football team, or some nuclear weapons, but at the very least you need a BEER.

- Frank Zappa
“In wine there is wisdom, in beer there is strength, in water there is bacteria.”
David Auerbach (2002)

This quote belies some real chemistry which has allowed brewers to successfully create safe drinking experiences, and enjoy unique beer styles. Over the years, water sources have been an important determinant for where breweries have been located. The notion of best ales in the Empire from Burton on Trent, and the clearest pale lagers from Pilsen is inextricably linked to the chemistry of the water.
Contents

• Water in Brewing
• Water as an ingredient
  – Brewhouse Chemistry
  – Water and Taints
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Outline of SABMiller and SAB Ltd

- The South African Breweries Limited was founded in 1895
- The company became SABMiller plc in 2002 when it purchased the Miller Brewing Company in the US
- SABMiller is listed in London and Johannesburg
- SABMiller is the world’s second largest brewer by volume
- The company has interests in more than 60 countries on four continents, and produces more than 150 brands.
- SAB Ltd is the South African operation of SABMiller plc and currently produces 25.9-million hectolitres of beer per annum and 14-million hl of other beverages through its soft drinks division, ABI. Including Bavaria, SABMiller produces 187-million hectolitres of beverages a year, of which 143-million are beer.
Water in Brewing

Water is essential in brewing as an ingredient and as a process facilitator.

Ingredient:
- Beer is composed of 90 – 95% water (typically)
- Water is the main ingredient and is added to the malt to create the mash in the brewhouse process
- Some brewers who brew at high gravity may add water back at filtration

Process facilitator:
- Water is an essential component for cleaning and rinsing and in various production processes such as pasteurisation, steam generation and CO2 management

The composition and quality of the water is vitally important for:
- Brewhouse chemistry
- Anti-taint assurance
- Microbiological impact
Brewhouse Process

2.1 Milling

2.2 Mashing

Solid adjuncts
water

2.3 Lautering

2.4 Boiling

hops

2.5 Whirlpool

2.6 Wort Cooling

2.7 High Gravity
Filtration process

5. Filtration

6.1 BBT/PR

7. Packaging

CO2

water
Brewhouse Chemistry

In the brewhouse, the main objectives are:

a) Create a simple sugar mix for the yeast to use to create alcohol
   • The role of water and minerals is critically important at this point
   • pH
   • Hardness/alkalinity

b) Sterilise the wort
Brewhouse Chemistry

During mashing, the presence of minerals is critically important for a number of reasons:

<table>
<thead>
<tr>
<th>Mineral</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Calcium</strong></td>
<td>The calcium ion is by far the most influential mineral in the brewing process. Calcium reacts with phosphates, forming precipitates that involve the release of hydrogen ions and in turn lowering the pH of the mash. This lowering of the pH is critical in that it provides an environment for alpha-amylase, beta-amylase, and proteolytic enzymes.</td>
</tr>
<tr>
<td><strong>Magnesium</strong></td>
<td>Magnesium ions react similarly to calcium ions, but since magnesium salts are much more soluble, the effect on wort pH is not as great. Magnesium is most important for its benefit to yeast metabolism during fermentation. Magnesium carbonate reportedly gives a more astringent bitterness than does calcium carbonate.</td>
</tr>
<tr>
<td><strong>Sodium</strong></td>
<td>Sodium has no chemical effect; it contributes to the perceived flavor of beer by enhancing its sweetness. Levels from 75 to 150 ppm give a round smoothness and accentuate sweetness, which is most pleasant when paired with chloride ions than when associated with sulfate ions. In the presence of sulfate, sodium creates an unpleasant harshness, so the rule of thumb is that the more sulfate in the water, the less sodium there should be (and vice versa).</td>
</tr>
<tr>
<td><strong>Potassium</strong></td>
<td>Like sodium, potassium can create a &quot;salty&quot; flavor effect. It is required for yeast growth and inhibits certain mash enzymes at concentrations above 10 mg/l.</td>
</tr>
<tr>
<td><strong>Sulphates</strong></td>
<td>Sulfates positively affects protein and starch degradation, which favors mash filtration and trub sedimentation. However, its use may result in poor hop utilization (bitterness will not easily be extracted) if the levels are too high. It can lend a dry, crisp palate to the finished beer; but if used in excess, the finished beer will have a harsh, salty, and laxative character.</td>
</tr>
</tbody>
</table>
## Brewhouse Chemistry

| **Phosphates** | Phosphates are important pH buffers in brewing and useful for reducing the pH in mashing and during the hop-boil |
| **Chlorides** | Calcium and magnesium chlorides give body, palate fullness, and soft-sweet flavor to beer. The certain roundness on the palate given by sodium chloride (common table salt) makes this salt eminently suited for all types of sweet beers – for both dark beers and stouts. |
| **Carbonates** | The presence of carbonate ions and their effect in raising pH can result in less fermentable worts (a higher dextrin/maltose ratio), unacceptable wort color values, difficulties in wort filtration, and less efficient separation of protein and protein-tannin elements during the hot and cold breaks. |
| **Nitrates and Nitrites** | Nitrate, in and of itself, is not a problem; it has no effect on beer flavor or brewing reactions. However, high nitrite levels may reduce the fermentation rate, dampen the rate of pH reduction, and give rise to higher levels of vicinal diketones |
| **Iron** | Iron in large amounts can give a metallic taste to beer. Iron salts have a negative action at concentrations above 0.2 mg/l during wort production, preventing complete saccharification, resulting in hazy worts, and hampering yeast activity. Radically promote staling through iron based hydroxy radicl formation. |
| **Copper** | Copper, in concentrations as low as 0.1 mg/l can act as catalysts of oxidants thus leading to irreversible beer haze. At levels more than 10 mg/l, copper is toxic to yeast |
| **Zinc** | Zinc plays an important role in fermentation and has a positive action on protein synthesis and yeast growth. It also impacts flocculation and stabilizes foam (promotes lacing) |
| **Manganese** | Manganese is important for proper enzyme action and has a positive action on protein solubilization and yeast |
Brewhouse Chemistry

pH in the Brewhouse:

• pH in mashing is critical or the activity of various enzymes in mashing (alpha & beta amylase, and proteolytic enzymes).

• pH in lautering is important as raised pH allows the extraction of the neutral tannins which contribute harsh and astringent flavours.

• pH of the boil is critical to form a good hot break. Ideally pH of 5.0 – 5.5 should be held to encourage the precipitation of protein.
Brewhouse Chemistry - hardness

Total water hardness is the measure of the salts present, the most common being bicarbonate, calcium, and magnesium ions present in the water. Total hardness is expressed as mg/l of calcium carbonate (CaCO₃).

Generally,
- < 50 mg/l is considered very soft water,
- 50 to 100 mg/l is considered soft water,
- 100 to 200 mg/l is considered medium-soft water,
- 200 to 400 mg/l is considered moderately hard water,
- 400 to 600 mg/l is considered hard water, and
- > 600 mg/l is considered very hard water.

Temporary Hardness
This hardness is due to carbonates and bicarbonates of magnesium and calcium and can be removed by high temperatures as CO₂ boils off. ↑alkalinity, ↑pH.

Permanent Hardness
Permanent hardness is that portion of total hardness remaining after the water has been boiled. Permanent hardness results from calcium and magnesium salts of sulfates and chlorides remaining in the water.
Brewhouse Chemistry

**Alkalinity in the Brewhouse:**

Alkalinity is a measure of the buffering capacity of the bicarbonate ions and, to some extent, the carbonate and hydroxide ions of water. These three ions all react with hydrogen ions to reduce acidity and raise pH. Expressed as mg/l as calcium carbonate (CaCO3) for all three ions.

**Residual Alkalinity**
This is related to permanent hardness and is also determined by the removal of bicarbonates.

Alkalinity is important because of its impact on pH, and because of the contribution to mineral composition.

**Where are these parameters managed?**
Water balancing is done prior to mashing to ensure the correct conditions for enzymatic function and correct extraction of malt components such as polyphenols.
Alkalinity (and temporary hardness) is typically reduced by addition of calcium sulphate.
Brewhouse Chemistry

How does this impact on the beer product:

High pH, and high alkalinity water (permanently hard) results in extraction of tannins and astringent flavours.

Lower pH high alkalinity water (typically non carbonate) results in crisp full bodied beers such as the Ales.

Water with elevated hardness is good for brewing dark beers, such as extra strong bitters, stouts, and ales. This is because the dark roasted malts lower the pH of hard water, and facilitate the reduction of the alkalinity and pH.

Soft water is better for pale lagers with good hop character. If they are brewed in hard water, they end up being very hard and astringent.

This has been learned over the years, with brewers who brew dark beers being situated near hard water sources, and pale lagers close to soft water sources. Typically the waters of Dublin are hard, those of Burton on Trent are high in calcium sulphate, and those of Pilsen (the home of clear lagers – are soft waters.)
Water and Taint

Water is a common source of Taints in beer

Typically, water is the source of the majority of taints associated in beer:

a) Chlorine – which in organic media is mostly converted to substituted chlorophenols such as tri-chlorophenols (TCP, medicinal taints)

b) Salty – certain waters are raised in sodium (boreholes close to the sea). Typically, $[\text{Na}] > 50$ ppm are perceived as salty

c) Metallic – water raised in iron tastes “rusted” and “bloody”. Typically $[\text{Fe}^{2+}] > 0.05$ ppm are perceived organoleptically

d) Trihalomethanes – occasionally in some treated waters. These can also lend a musty odour and taint.
Water and Micro-organisms

Water is a source of a number of micro-organisms:

- Pseudomonas spp
- Coliforms
- Yeasts and Fungi

The majority of micro-organisms cannot survive the harsh environment of beer (low pH, raised alcohol, and hop alpha acids).

Boiling of water in the brewing process, and the wort boiling typically sterilises the water or wort.
Our systems to manage

In most breweries, water is managed as follows:

1. Water Hygiene and taint management
2. Water treatment for suitability at point of use
Our systems to manage

In most breweries, water is managed as follows:

a) Quality assurance monitoring of incoming water, through SPP relationships with the supply municipality (monitoring of THMs, micro-organisms, salts, ions).

b) Quality control of pH, hardness, chlorine and microorganisms of incoming water – conducted by our laboratories.

c) Chlorination of incoming water to remove any residual microorganisms. Water is held in treatment reservoirs.

d) De-chlorination of water through activated carbon filters.
   • This step is followed by a QC check for chlorine.
   • Annual QC also includes the checks for absorption and carbon activity.
   • Daily taste checks for chlorine and other taints (metallic and THMs)

e) Quality assurance and due diligence (annual) pesticides, herbicides, metals, and other compounds, external 3rd party lab
In most breweries, water is managed as follows:

a) Boiling of water to remove temporary hardness

b) Acidification of mash water (lactic acid)

c) Addition of brewing salts to increase softness (addition of calcium chloride, or calcium sulphate)
Water as a process facilitator

Water is used to facilitate the following activities:

a) Steam generation
b) CIP and rinsing of tanks and vessels
c) Bottle washing
d) Pasteurisation

None of these activities are considered product contact activities. However, there are a number of processes that are in place to manage water quality and suitability, such as:

a) Water softening for boiler water
b) Addition of acids and alkalines to the CIP process
c) Heat to bottle washer water
d) Treatment of pasteuriser water with sterilising agents.

Water quality is generally monitored by the Utilities operators for point of use suitability.
The Sustainable Use of Water

• Extreme targets for water usage
• Reduction of use of water at all non product related water
  – Re-use of water such as pasteuriser water, through treatment
• Certain breweries in India have pioneered the use of treated water through to agricultural land adjoining the brewery
• Ibhayi brewery – Project Eden – for fish farming and hydroponic vegetable farms
Thank you

• Any questions?