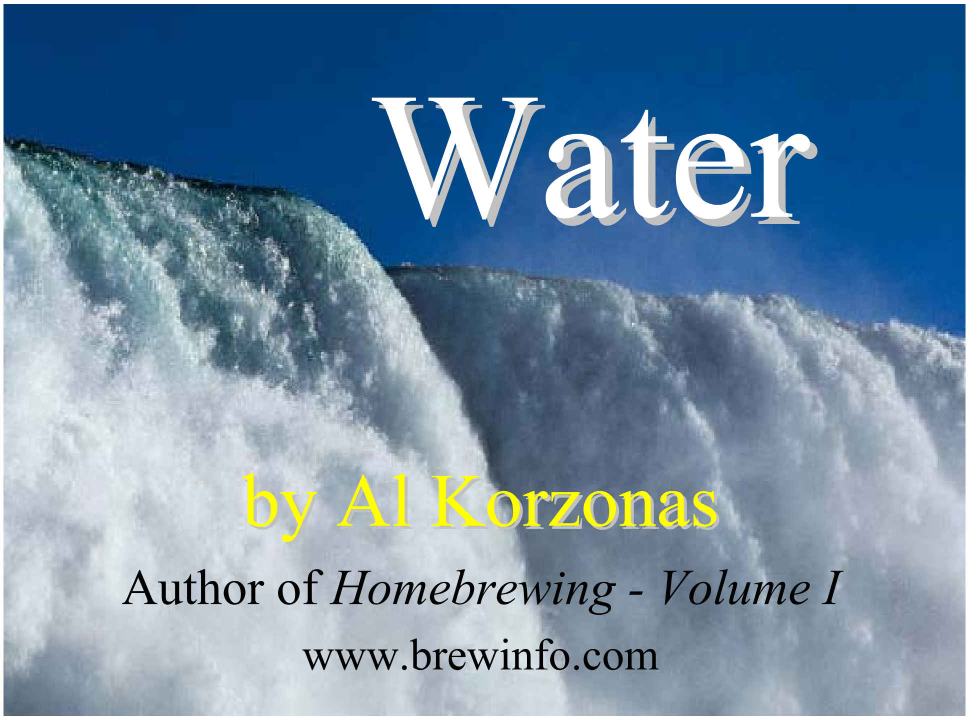

* these are the viewgraphs and notes from the talk I did at the 2003 American Homebrewers Conference in Chicago

* the majority of the information in this lecture was taken from my book, *Homebrewing - Volume I,* which is available from many homebrew shops or from my website http://www.brewinfo.com.

* PLEASE NOTE THE ADDITIONAL INFORMATION ON PAGE 5 THAT WAS NOT IN THE LECTURE!

- What's good water?
- Chlorine and chloramines
- Softeners and filters
- The effects of ions on beer
- pH, Alkalinity and Hardness
- Matching waters to styles
- Famous brewing waters
- Adjusting your water

What's good water?

- What's bad water?
  - unpotable
  - sulphury
  - musty
  - fishy
  - algae
  - excessive ions

* water you can't drink isn't good for making beer: industrial or agricultural runoff, lead, arsenic, cadmium, etc.

* smelly water isn't good: sulphury, musty, fishy, algae aromas

* zebra mussels in Lake Michigan - carbon filter

* iron above 0.05ppm begins to give a metallic flavor; iron above 1ppm can cause haze

* some ions are easy to remove (like iron) and others difficult (like sodium)

Chlorine and chloramines

- added to most municipal waters
- if left in the water, will react with phenolic compounds to make chlorophenols
- boiling and carbon filtering remove chlorine
- chloramines require either activated carbon filtering, metabisulfite, or UV to eliminate them

* most municipal waters contain either chlorine or chloramines for the purpose of preventing bacterial or algae growth

* boiling or carbon filtering removes enough chlorine to make water suitable for brewing

* only certain carbon filters will remove chloramines according to Jim Booth's research; A J deLange posted a method for removing chloramines with metabisulfites to the Homebrew Digest #3304: one metabisulfite tablet (about 700mg potassium metabisulfite) will remove the typical levels of chloramine from 20 gallons of water; according to www.aquafineuv.com, chlorine and chloramines can be removed with UV light

Softeners and filters

- if you have an salt-based softener, bypass it for brewing
- reverse-osmosis will produce virtually ion-free water, but you should add back at least some calcium in the form of gypsum or calcium chloride (depending on the style)
- activated carbon filter

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* “hard water” is essentially water high in calcium; desirable for brewing, undesirable for washing dishes and clothes and making coffee

* a salt-based softener works by replacing calcium with sodium

* an activated carbon filter will remove chlorine and chloramines, some metallic ions, and some smells; if you can afford to run all your brewing water through one, do it (CORRECTION: SEE BELOW)

* note that R-O water is very reactive, so you should plumb your R-O water with plastic rather than metal pipes

* just by chance I ran across a post from AJ deLange (hbd #2838) today (6/23/2003, two days after this lecture was given) and found that in this post AJ said that *some* activated carbon filters (for example, the Brita filters) also contain ion-exchange media, which will remove some of the calcium, carbonate, sulfate, and other ions in your water; so, depending on the type of filter you have, carbon-filtered water may be lower in some ions than before filtering; also, in that post, AJ noted that campden tablets used to remove chlorine and chloramines will add a small amount of sulfate to your water (if all the sulfite is converted, one tablet in 20 gallons will add about 9ppm of sulfate)

The effects of ions on beer

- the mash/steep/boil
- yeast
- haze and colloidal stability
- flavour

Effects on the mash/steep/boil

- calcium lowers mash/steep pH, assists starch gelatization, protects enzymes from denaturing, helps extract hop bitterness, and lightens wort colour
- carbonate and bicarbonate increase mash/steep/boil pH, and impede starch gelatization

- manganese is important to some enzymatic reactions, but malt should provide plenty
- magnesium is important to some enzymatic reactions, but 10 to 20 ppm is plenty
- phosphate is important in the mash and steep, but it is flavour neutral and the malt provides all you need
- potassium can interfere with enzymatic reactions, although some British Ales contain 1100ppm
- zinc is crucial to many enzymatic processes

Effects on yeast

- carbonate/bicarbonate can interfere with yeast flocculation
- high levels of chloride can interfere with yeast flocculation
- copper is important for yeast nutrition in small amounts
- iron can affect yeast in high concentrations

- magnesium is a yeast nutrient at low levels (10 to 20ppm)
- potassium is necessary for yeast growth, but you need not worry about adding it to your water
- excessive sodium is harmful to yeast
- higher levels of zinc can promote yeast autolysis
- insufficient calcium and potassium can cause flocculent yeasts to become powdery after a few generations; this is reversable

* according to the 1909 book Brewing Water: Its Defects and Their Remedy, published by the American Burtonizing Company of New York City, their research indicates that brewing with calcium- and potassium-deficient water will cause otherwise well-flocculating yeast to become powdery over the course of several generations; conversely, providing enough calcium and potassium, will, over the course of several generations, cause these yeasts to become properly flocculent again

Haze and colloidal stability

- Nearly ion-free water results in beer with the lowest colloidal stability
- acidifying salts (chloride or sulfate) of calcium and magnesium improve the colloidal stability
- colloidal stability increases with increased water hardness
- calcium sulfate and sodium chloride additions decrease chill haze

* from M. Moll, "Colloidal Stability of Beer" in Brewing Science, Vol 3, edited by Pollock, p 117

- iron concentrations over 1 ppm result in irreversible colloidal haze
- copper concentrations over 1 ppm result in irreversible hazes
- copper concentrations above 0.1 ppm decreases colloidal stability
- increased silica results in higher haze

* from M. Moll, "Colloidal Stability of Beer" in Brewing Science, Vol 3, edited by Pollock, p 118-119

Effects on flavour

- contrary to what many books say, carbonates/bicarbonates do not directly impart "harsh, bitter" flavour
- they raise the pH of the mash/steep which, in turn, causes increased polyphenol (tannin) extraction which results in harsh, astringent beer, especially when oxidised

- higher pH also results in increased hop utilization, which can result in unexpected and possibly unwanted bitterness
- chloride accentuates sweetness, increases palate fullness, and smoothes bitterness
- iron and maganese levels above 0.5 ppm give a metallic flavour
- sodium accentuates flavour, but can be unpleasant at high concentrations
- sulfate accentuates hop bitterness and lends a long, dry finish to beer

pH, Alkalinity and Hardness

- *pH* is the measure of the acidity of a liquid; it ranges from 1 (acidic) to 14 (alkaline)
- *alkalinity* tells you how your water will react with the addition of acid; it is mathematically defined as the concentration of bicarbonate, plus two times the concentration of carbonate, plus the concentration of hydroxide, minus the concentration of hydrogen ions

* according to The Practical Brewer book, good brewing water should have its alkalinity reduced to 50 ppm or less and have at least 50 ppm of calcium (80 to 100 is preferred)

* Moll's article in Brewing Science Volume I, says Alkalinity should be below 50 ppm (0-25 is preferred), Chloride below 250ppm, Sulfate below 500 ppm (although this is dependent on the style… see below), Copper below 3.0 ppm, Manganese below 0.3 ppm, and Zinc below 5 ppm.

* I'd like to add that for Bohemian/Czech Pilseners, sulfate should be below about 10 ppm

- *hardness* is primarily a measure of calcium and magnesium in your water
- total hardness is the sum of carbonate and non-carbonate hardness
- hardness is usually a blessing to a brewery (unless you are trying to brew a Czech Pilsener)
- all hardness is either "temporary" or "permanent"; temporary can be removed by boiling and decanting; permanent cannot be removed in this way

* when you boil water with temporary hardness, you drive off dissolved CO_2, which results in an increased pH, which then subsequently results in some of the calcium carbonate in the water to precipitate out, thereby reducing the (temporary) hardness; you should then decant the water off the white precipitate

* how much can be removed is dependent on how much calcium you have

* calcium sulfate is far more soluble in water and will not react in this way

* if you have a lot of carbonate hardness and you do this, you should add back some calcium as calcium chloride (if you are making a low-sulfate beer, like Pilsener) or calcium sulfate (if you are making a high-sulfate beer, like Bitter

* note that actually, despite the often-repeated statement that "Czech and Bohemian Pilseners must be brewed with soft water," you can brew these beers with moderately hard water and still have them taste authentic; the key is to remember that hardness is a measure of calcium and magnesium and that what's really important in Czech and Bohemian Pilseners is to have low sulfate; if you add calcium as calcium chloride, you can have moderately hard water and yet still have low sulfate

Brainerd Water Analysis	
Total Hardness	240 mg/l or 14.0 grains/gal
Alkalinity	230 mg/l
Calcium	160 mg/l
Magnesium	80 mg/l
Iron	< 0.05 mg/l
Manganese	<0.02 mg/l
Chloride	9.4 mg/l
Sulfate	18 mg/l
Potassium	2 mg/l
Sodium	8.1 mg/l

* note that the alkalinity is quite high; so this water will result in high pH; also, note that sulfate and chloride are quite low, but that there’s a lot of calcium and magnesium; that suggests that there’s a lot of carbonate/bicarbonate

Mercy Hot Springs Water Analysis

Carbonates	33.0 ppm
Bicarbonates	None
Manganese	None
Zinc	223 ppb
Iron	0.1 ppm
Calcium	39.5 ppm
Chloride	1294.3 ppm
Magnesium	6.8 ppm
Potassium	6.2 ppm
Sodium	794.0 ppm
Sulfate	1.6 ppm
Phosphates	0.36 ppm

* alkalinity is low because carbonates and bicarbonates combined is only 33 ppm

* sulfate is low

* sodium and chloride are excessive… this is very salty water; unsuitable for brewing unless run through an R-O filter or distilled

Matching waters to styles

- use low-sulfate water for beers where the sulfate accentuation of the hop bitterness is not desirable (e.g. Bohemian Pilsener), and to high-sulfate water for beers that do (e.g. Bitter, IPA, Dortmunder)
- use low-carbonate water for pale beers and high-carbonate water for dark beers

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* see the “Waters For Particular Styles” excerpt from my book, after this set of viewgraphs

Famous Brewing Waters

- See the attached excerpt from my book

* see the “Famous Brewing Waters” excerpt from my book, after this set of viewgraphs

Adjusting your water

- don’t worry too much about matching some famous brewing water perfectly
- when in doubt, refer back to the two main rules under “Matching waters to styles”

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* see “Adjusting Water With Salts” excerpt from my book, after this set of viewgraphs