MODELING WATER CHEMISTRY CHANGES DURING THE DRINKING WATER TREATMENT PROCESS

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Outline

- Need for Modeling
- Treatment Process
- Goals for Modeling
- Modeling Procedure
- Future Work/Improvements
- Questions

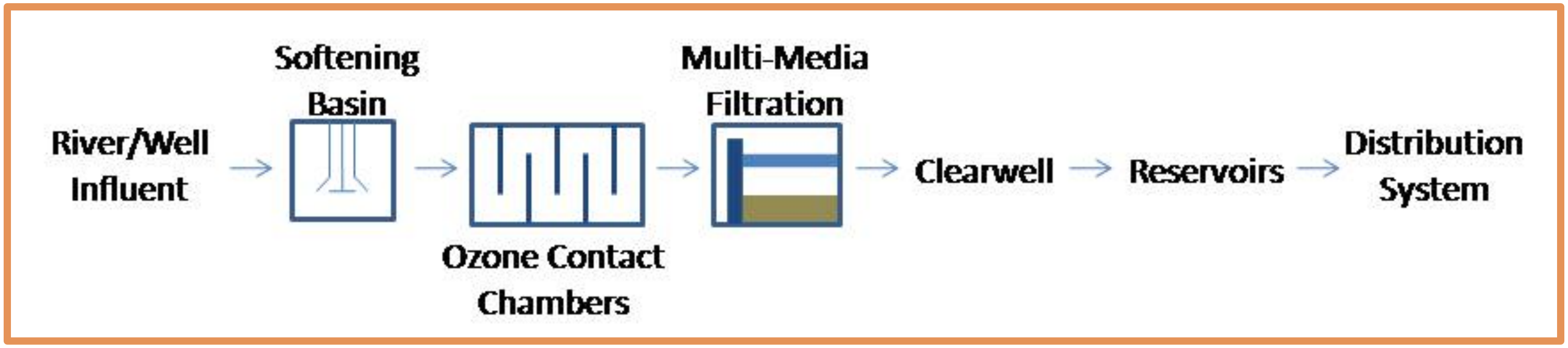
Need for Modeling

- Different Source Waters
  - Mixing ratios between river and wells constantly change
  - Different water sources have different chemistry
  - Better understanding would improve:
    - Chemical use efficiency
    - Better treatment
    - Save money

- Not much published yet

Treatment Process

- Moorhead Water Treatment Plant (MWTP)



  - Influent Water Mixing
  - Sedimentation and Softening
  - Ozone Disinfection/Recarbonation
  - Multi-media Filtration

Goals for Modeling

- Three Processes:
  - Mixing
  - Softening
  - Recarbonation
- Mixing
  - Determine combined hardness and pH
- Softening
  - Hardness: 88 to 108 mg/L as $CaCO_3$
  - pH: 10.5 to 11.5
- Recarbonation
  - Hardness: 88 to 108 mg/L as $CaCO_3$
  - pH of 9.5 to 9.7

Modeling Procedure

- Influent Water Chemistry
- Mixing

Simulation 1

- Softening

Simulation 2

- Recarbonation

Simulation 3

Mixing Model

- Water Sources
  - Groundwater (GW)
    - Buffalo Aquifer
  - Surface Water
    - Red River




Mixing Model

Parameter/Constituent (unit)	Red River	GW
Temperature (°C)	25.08	8.58
pH(units)	8.2	7.6
Oxidation Reduction Potential (mV)	47	96.5
Alkalinity, Bicarbonate (mg/L)	190	330
Alkalinity, Carbonate (mg/L)	2.6	1.3
Alkalinity, Total (mg/L)	190	330
Barium (µg/L)	76.9	46.6
Bromide (mg/L)	0.0496	0.0744
Calcium (mg/L)	51	94.6
Chloride (mg/L)	13	14.9
Iron (µg/L)	851	1050
Magnesium (mg/L)	37.3	36.9
Manganese (µg/L)	70.4	120
Phosphate, Total (mg/L)	0.424	0.272
Potassium (mg/L)	4.6	5
Sodium (mg/L)	0.5	62.5
Strontium (µg/L)	200	504
Sulfate (mg/L)	86.7	170
Dissolved Oxygen (mg/L)	3.3	0.32

Mixing Model

```
SOLUTION 1 Red River
    temp       25.08
    pH         8.2
    pe         0.7945
    redox      pe
    units      mg/l
    density    1
    Alkalinity 190 as HCO3
    Ba         0.0769
    Br         0.0496
    Ca         51
    Cl         13
    Fe         0.851
    Mg         37.3
    Mn         0.0704
    P          0.424
    K          4.6
    Na         0.5
    Sr         0.2
    S(6)       86.7
    O(0)       3.3
    -water     1 # kg
```

```
SOLUTION 2 Well 9
    temp       8.58
    pH         7.6
    pe         1.73
    redox      pe
    units      mg/l
    density    1
    Alkalinity 330 as HCO3
    Ba         0.0466
    Br         0.0744
    Ca         94.6
    Cl         14.9
    Fe         1.05
    Mg         36.9
    Mn         0.12
    P          0.272
    K          5
    Na         62.5
    Sr         0.504
    S(6)       170
    O(0)       0.32
    -water     1 # kg
```

```
MIX 1
    1    0.72
    2    0.28
SAVE solution 3
END
```

Mixing Model

Prior to Mixing

- Phreeqcl Speciation
  - Ionic Strength
    - Red River: 8.262e-3
    - GW: 1.410e-2
  - Hardness
    - Red River: 252.50 mg/L
    - GW: 344.40 mg/L
  - pH
    - Red River: 8.2
    - GW: 7.6

After Mixing

- Phreeqcl Speciation
  - Ionic Strength
    - 9.892e-3
  - Hardness
    - 279.2 mg/L
  - pH
    - 7.8

Flows: River=2500 gpm and GW=995 gpm →5 MGD

Mixing Ratio: 72% River to 28% GW

Softening Model

- Hardness is measured by amount of Ca^{2+} and Mg^{2+}
- Hardness Causes:
  - Scale-pipes and fixtures
  - High soap consumption-no lathering
- Hardness Removal:
  - lime[$Ca(OH)_2$] and soda ash [Na_2CO_3]

1. $Mg^{2+} + CO_3^{2-} + Ca(OH)_2 \rightarrow Mg(OH)_2 \downarrow + CaCO_3 \downarrow$
2. $Ca^{2+} + Na_2CO_3 \rightarrow CaCO_3 \downarrow + 2Na^{+}$

  - precipitation of calicite [$CaCO_3$] and brucite [$Mg(OH)_2$]

Softening Model

- Input Code

```
USE solution 3
REACTION 1
    Portlandite 1
    Na2CO3     0.5
    0.002 moles in 1 steps
EQUILIBRIUM_PHASES 1
    Brucite    0 0
    Calcite    0 0
    Portlandite 0 0
SAVE solution 4
END
```

- PhreeqcI Results
  - Hardness: 96.1 mg/L
  - pH: 10.2

Recarbonation Model

- Addition of CO_2 (g)
  - Lowers pH of water
    - The softening process raises pH to a non-consumable level
- Input Code

```
USE solution 4
REACTION 2
    CO2(g)     1
    0.0003 moles in 1 steps
```

Recarbonation Model

- Phreeqcl Results
  - Hardness
    - 102.3 mg/L
  - pH
    - 9.71

Conclusions

- Phreeqcl is capable of mixing two different water sources to determine combined hardness and pH
- Phreeqcl can be used to simulate water softening through lime and soda ash
  - pH however is slightly lower than expected
- Phreeqcl simulates pH adjustments at a treatment plant

Future Work/Improvements

- Ozone Disinfection
  - The addition of O_3 (g) to the water
  - Formation of bromate (BrO_3^-)
- Filtration
  - pH reduction due to organics
- Removal of Organic Matter

References

- Davis M.L., Cornwell D.A. (2008). *Introduction to Environmental Engineering.* McGraw Hill, New York.

- United States Geological Survey (1998). Frequently asked questions for PHREEQC andPhreeqcl. http://wwwbrr.cr.usgs.gov/projects/GWC_coupled/phreeqc/faq.html

- Viessman W., Hammer M.J., Perez E.M. Chadik P.A. (2009). Water supply & pollution control. Pearson Education Inc., New Jersey.

Questions?