Formula/Conversion Table
for Water Treatment Plant and Water Distribution Systems

1 foot = 12 inches  
1 MGD = 1.55 cfs  
1 grain / gal = 17.1 mg/L  
1 minute = 60 seconds

1 yard = 3 feet  
1 cu. yd. = 27 cu. ft.  
1 gram = 1,000 mg  
1 hour = 60 minutes

1 meter = 3.28 feet  
1 cu. ft. = 7.48 gal  
1 kg = 1,000 gram  
1 day = 1,440 min

1 mile = 5,280 feet  
1 gal = 8.34 lbs  
1 liter = 1,000 ml  
1% = 10,000 mg/L

1 sq. ft. = 144 sq. in.  
1 cu. ft. = 62.4 lbs  
1 gal = 3.785 liters  
1 mg/l = 1 ppm

1 acre = 43,560 sq. ft.  
1 kg = 2.2 lbs  
1 psi = 2.31 ft. of water head  
1 hp = 0.746 kW

1 acre-ft. = 43,560 cu. ft.  
1 lb. = 454 g  
1 ft. of water head = 0.433 psi  
1 hp = 33,000 ft. lbs/min

1 acre-ft. = 325,829 gallons  
1 gram = 1,000 mg  
1 kWh = 1,000 Watts

1 sq. ft. = 144 sq. in.  
1 cu. ft. = 62.4 lbs  
1 gal = 3.785 liters  
1 kg = 2.2 lbs

1 liter = 1,000 ml  
1% = 10,000 mg/L  
1 gram = 1,000 mg  
1 kwh = 1,000 watts

Legend:  L = length  
W = width  
H = height  
R = radius  
D = diameter  
π = 3.14  
g = gram

Alkalinity Concepts

Phenolphthalein Alkalinity, mg/L as CaCO₃ = \[ \frac{(Titrant \ Volume \ A, \ ml) \ (Acid \ Normality) \ (50,000)}{Sample \ Volume, \ ml} \]

Total Alkalinity, mg/L as CaCO₃ = \[ \frac{(Titrant \ Volume \ B, \ ml) \ (Acid \ Normality) \ (50,000)}{Sample \ Volume, \ ml} \]

Alkalinity Relationships: Alkalinity, mg/l as CaCO₃

<table>
<thead>
<tr>
<th>Result of Titration</th>
<th>Bicarbonate Alkalinity as CaCO₃</th>
<th>Carbonate Alkalinity as CaCO₃</th>
<th>Hydroxide Alkalinity as CaCO₃</th>
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<tbody>
<tr>
<td>P = 0</td>
<td>T</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>P &lt; ½ T</td>
<td>T – 2P</td>
<td>2P</td>
<td>0</td>
</tr>
<tr>
<td>P = ½ T</td>
<td>0</td>
<td>2P</td>
<td>0</td>
</tr>
<tr>
<td>P &gt; ½ T</td>
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<td>2P – T</td>
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<tr>
<td>P = T</td>
<td>0</td>
<td>0</td>
<td>T</td>
</tr>
</tbody>
</table>

Key: P – phenolphthalein alkalinity; T – total alkalinity

Area, Circumference and Volume

Area, square feet (ft²)
Circle: \( A = 3.14 \times R^2 \) or \( A = 0.785 \times D^2 \)
Cylinder, (total outer surface area): \( A = (2 \times 3.14 \times R^2) + 3.14 \times D \times H \) or \( A = (2 \times 0.785 \times D^2) + (3.14 \times D \times H) \)
Cylinder (pipe): \( A = 3.14 \times D \times L \)
Square or Rectangle: \( A = L \times W \)

Circumference (Perimeter), linear feet
Circle = \( 3.14 \times D \)
Rectangle = \( (2 \times L) + (2 \times W) \)

Volume, cubic feet (ft³):
Cylinder: \( V = 3.14 \times R^2 \times H \) or \( V = 0.785 \times D^2 \times H \)
Rectangle: \( V = L \times W \times H \)
Average (arithmetic mean) = \[
\frac{\text{Sum of All Terms or Measurements}}{\text{Number of Terms or Measurements}}
\]

Annual Running Average = \[
\frac{\text{Sum of All Averages}}{\text{Number of Averages}}
\]

**Chemical Feed, Mixing and Solution Strengths**

Chemical Feed, lbs/day = 
\[
\frac{(\text{Dry Chemical, g}) (60 \text{ min/hr.}) (24 \text{ hr./day})}{(454 \text{ g/lb.}) (\text{Time, min})}
\]

Chemical Feed, lbs/day = 
\[
\frac{(\text{Polymer Conc., mg/l}) (\text{Volume Pumped, ml}) (60 \text{ min/hr.}) (24 \text{ hr./day})}{(\text{Time Pumped, min}) (1,000 \text{ mg/l}) (1,000 \text{ mg/gm}) (454 \text{ gm/lb.})}
\]

Chemical feed pump setting, % stroke = \[
\frac{\text{Desired feed flow, gpd}}{\text{Maximum feed flow, gpd}} \times 100\%
\]

Chemical Feed Pump Setting, mL/minute = 
\[
\frac{\text{(Flow, MGD)} (\text{Dose, mg/L}) (3.785 \text{ L/gal}) (1,000,000 \text{ gal/MG})}{(\text{Liquid alum, mg/ml}) (1,440 \text{ min/day})}
\]

Chemical Flow, gpm = \[
\frac{\text{Volume Pumped, gal}}{(\text{Pumping Time, hr}) (60 \text{ min/hr})}
\]

Feeder setting, % = 
\[
\frac{\text{Desired feed rate, lbs./day}}{\text{Maximum feed rate, lbs./day}} \times 100\% \quad \text{or} \quad \frac{\text{Desired flow, gpd}}{\text{Maximum flow, gpd}} \times 100\%
\]

Hypochlorite Strength, % = \[
\frac{\text{Chlorine required, lbs/day}}{(\text{Hypochlorite solution needed, gal/day}) (8.34 \text{ lbs./gal})} \times 100\%
\]

Lbs. of Chemical = 
\[
\frac{\text{(amount of solution needed, gal}) (\text{solution strength, as a decimal}) (8.34 \text{ lbs/gal})}{\text{8.34 lbs/gal}}
\]

Liquid Polymer, gal = \[
\frac{(\text{Polymer Solution, %}) (\text{gal of solution})}{\text{Supplied Liquid Polymer, %}}
\]

Mixture Strength, % = 
\[
\frac{(\text{Amount 1, gals}) (\text{Strength 1, %}) + (\text{Amount 2, gals}) (\text{strength 2, %})}{(\text{Amount 1, gals}) + (\text{Amount 2, gals})}
\]

Polymer Solution, % = \[
\frac{(\text{Dry Polymer, lbs}) (100\%)}{(\text{Dry Polymer, lbs} + \text{Water, lbs})}
\]

Water added for hypochlorite sol’n, gal = \[
\frac{(\text{hypo, gal}) (\text{hypo,\%}) - (\text{hypo, gal}) (\text{desired hypo,\%})}{\text{Desired hypo, \%}}
\]

Potassium Permanganate Dose, mg/L = \[
(0.2 \times \text{Iron content, mg/L}) + (2.0 \times \text{Manganese content, mg/L})
\]

**Demineralization**

Membrane Area, sq ft = (Number of Vessels) (Number of Elements per Vessel) (Surface Area per Element)
Mineral Rejection, % = \( \left( 1 - \frac{\text{Product TDS Concentration, mg/L}}{\text{Feedwater TDS Concentration, mg/L}} \right) \times 100\% \)

Recovery, % = \( \frac{\text{Product Flow, MGD}}{\text{Feed Flow, MGD}} \times 100\% \)

**Detention Time**

Detention Time, days = \( \frac{\text{Tank Volume, gallons}}{\text{Flow Rate, gal/day}} \)

Note: for detention time in hours, multiply by 24 hrs/day

For detention time in minutes, multiply by 1,440 min/day

**Disinfection**

Chlorine Demand, mg/L = Chlorine Dosage, mg/L − Chlorine Residual, mg/L

Chlorine Dosage, mg/L = Chlorine Demand, mg/L + Chlorine Residual, mg/L

Chlorine Residual, mg/L = Chlorine Dosage, mg/L − Chlorine Demand, mg/L

CT calculation, time = (Disinfectant Residual Concentration, mg/L) (Time) Time units must be compatible

**Electrical**

\[ \text{Amps (I)} = \frac{\text{Volts (E)}}{\text{Ohms (R)}} \]

Electromotive Force (EMF), volts = (Current, amps) (Resistance, ohms) or \( E = I \times R \)

Power, kilowatts (3 phase AC circuit) = \( \frac{(E, \text{volts}) (I, \text{amps}) (\text{Power Factor}) (1.73)}{1,000 \text{ watts/kilowatt}} \)

Power, kilowatts (single phase AC circuit) = \( \frac{(E, \text{volts}) (I, \text{amps}) (\text{Power Factor})}{1,000 \text{ watts/kilowatt}} \)

Power, watts (DC circuit) = (E, volts) (I, amps) or \( P = E \times I \)

Power Output, horsepower = \( \frac{(\text{Power Input, Kw x Efficiency, \%})}{0.746 \text{ Kw/ Hp}} \times 100\% \)

Power Requirements, kW-hr = (Power, kilowatts) (Time, hours)

**Feed Rate, 100% chlorine**

Feed Rate, lbs/day = (Dosage, mg/L) (Flow, MGD) (8.34 lbs/gal)

Using the Davidson Pie Chart

- To find the quantity above the horizontal line: Multiply the 3 pie wedges below the line together. Next, divide by the % purity as a decimal (i.e., 65% = 0.65).
- To solve for one of the pie wedges below the horizontal line: Divide the 2 bottom pie wedges into the quantity of lbs above the horizontal line. Next, multiply by the % purity as a decimal (i.e., 65% = 0.65).
- The given units must match the units shown in the pie wheel.
- Dose = mg/L or PPM
Calcium Hypochlorite (CaOCl), lbs. = \[ \frac{\text{Pure chlorine required, lbs/day}}{\text{CaOCl % Purity, as decimal}} \times 100\% \]

Sodium Hypochlorite (NaOCl), gals. = \[ \frac{\text{Pure chlorine required, lbs/day}}{(\text{NaOCl % purity as decimal}) (8.34 \text{ lbs/gal})} \times 100\% \]

**Filtration**

Backwash Rise Rate, inches/min = \( \frac{(\text{Backwash Rate, gpm/sq. ft.}) (12 \text{ in/ft})}{7.48 \text{ gal/cu. ft.}} \)

Backwash Pumping Rate, gal/min = \( (\text{Backwash Rate, gpm/sq. ft.}) (\text{Filter Surface Area, sq. ft.}) \)

Backwash Water Required, gal = \( (\text{Backwash Flow, gpm}) (\text{Backwash Time, min}) \)

Backwash Water Used, % = \[ \frac{\text{Backwash Water, gal}}{\text{Water Filtered, gal}} \times 100\% \]

Filtration Rate or Backwash Rate, gpm/sq ft = \[ \frac{\text{Flow Rate, gpm}}{\text{Filter Surface Area, sq ft}} \]

Hydraulic or Surface Loading Rate, gpd/sq ft = \[ \frac{\text{Total Flow Applied, gpd}}{\text{Surface Area, sq ft}} \]

Unit Filter Run Volume, gal/sq ft = \[ \frac{\text{Total Volume Filtered, gal}}{\text{Filter Surface Area, sq ft}} \]

Unit Filter Run Volume, gal/sq ft = \( (\text{Filtration Rate, gpm/sq. ft.}) (\text{Filter Run, hr}) (60 \text{ min/hr}) \)

**Flow Rates and Velocity (pipeline, channel or stream)**

Flow Rate, cfs = \( (\text{Area, sq. ft.}) (\text{Velocity, ft/sec}) \) or \[ Q = V \times A \]

Flow Rate, gpm = \( (\text{Area, sq. ft.}) (\text{Velocity, ft/sec}) (7.48 \text{ gal/cu ft}) (60 \text{ sec/min}) \)

Velocity, fps = \[ \frac{\text{Flow Rate, cfs}}{\text{Area, sq ft}} \] or \[ \frac{\text{Distance, ft}}{\text{Time, seconds}} \]

**Fluoridation**

Feed Rate, lbs/day = \[ \frac{(\text{Dosage, mg/L}) (\text{Flow, MGD}) (8.34 \text{ lbs/gal})}{(\text{Fluoride Sol'n, as a decimal}) (\text{Fluoride Purity, as a decimal})} \]

Feed Rate, gpd = \[ \frac{\text{Feed Rate, lbs/day}}{\text{Chemical Solution, lbs/gal}} \]

Feed Rate, lbs/day = \[ \frac{\text{Fluoride, lbs/day}}{\text{Fluoride, lbs/lb of commercial chemical}} \]
Fluoride Ion Purity, % = \( \frac{\text{Molecular Weight of Fluoride}}{\text{Molecular Weight of Compound}} \times 100\% \)

**Flushing Time**

Flushing Time, sec = \( \frac{\text{Volume, cu ft}}{\text{Flow, cfs}} \) or \( \frac{(\text{Length of Pipeline, ft})(\text{Number of Flushing Volumes})}{\text{Velocity, ft/sec}} \)

**Laboratory**

Dilute to ml = \( \frac{(\text{Actual Weight, gm})(1,000 \text{ ml})}{\text{Desired Weight, gm}} \)

Langelier Saturation Index (L.S.I.) = \( \text{pH} - \text{pH}_s \)

**Leakage and Pressure Testing Pipelines**

Leakage, gpd = \( \frac{\text{Volume, gal}}{\text{Time, days}} \)

Asbestos Cement (AC) or Ductile Iron (DI) Pipe, gpd/mi-in = \( \frac{\text{Leak Rate, gpd}}{(\text{length, miles})(\text{Diameter, in})} \)

Plastic Pipe Leakage, gph/100 joints = \( \frac{\text{Leak Rate, gph}}{(\text{Number of Joints ÷ 100})} \)

Test Pressure, psi = Normal Pressure + 50% or 150 psi, whichever is greater

**Loading**

Weir Overflow Rate, gpd/ft = \( \frac{\text{Total Flow, gpd}}{\text{Length of Weir, ft}} \)

**Parts per million (PPM) or milligrams per liter, (mg/L)**

Dosage, PPM or mg/L = \( \frac{\text{Pounds of Chemical, lbs}}{\text{(Water Volume, MG})(8.34 \text{ lbs/gal})} \)

**Pressure and Head**

Head (Height of Water), ft = (Pressure, psi) (2.31 ft/psi) or Head (Height of Water), ft = \( \frac{\text{Pressure, psi}}{0.433 \text{ psi/ft}} \)

Pressure, psi = \( \frac{\text{Head, ft}}{2.31 \text{ ft/psi}} \) or Pressure, psi = (Head, ft) (0.433 psi/ft)

**Pumps, Motors and Horsepower**

Water Horsepower (WHP) = \( \frac{(\text{Flow, gpm})(\text{Head, ft})}{3,960} \)

Brake Horsepower (BHP) = \( \frac{(\text{Flow, gpm})(\text{Head, ft})}{(3,960)(\text{Pump Efficiency as decimal})} \)

Motor Horsepower (MHP) = \( \frac{(\text{Flow, gpm})(\text{Head, ft})}{(3,960)(\text{Pump Efficiency as decimal})(\text{Motor Efficiency as decimal})} \)

Pumping Rate, gpm = \( \frac{\text{Volume, gal}}{\text{Time, min}} \)
Total Dynamic Head, ft = Static Head, ft + Discharge Head, ft + Friction Loss, ft

Wire-to-Water Efficiency, % = \[ \frac{\text{Water Horsepower, WHP}}{\text{Power Input, (Brake Hp or Water Hp)}} \times 100\% \]

Wire-to-Water Efficiency, % = \[ \frac{(\text{Flow, gpm}) (\text{Total Dynamic Head, ft})}{(\text{Voltage, volts}) (\text{Current, amps}) (5.308)} \times 100\% \]

Kilowatt-hr/day = \( (\text{Motor, Hp}) (\text{Motor Run Time, hr/day}) \times (0.746 \text{ kW/Hp}) \)

**Softening Processes**

### Hardness

Total Hardness, mg/l as CaCO_3 = Calcium Hardness, mg/l as CaCO_3 + Magnesium Hardness, mg/l as CaCO_3

If alkalinity is **greater** than total hardness:
- Carbonate Hardness, mg/l as CaCO_3 = Total Hardness, mg/l as CaCO_3 and,
- Noncarbonate Hardness, mg/l as CaCO_3 = 0

If alkalinity is **less** than total hardness:
- Carbonate Hardness, mg/l as CaCO_3 = Amount of total hardness up to the Total Alkalinity, mg/l as CaCO_3, or
- Noncarbonate Hardness, mg/l as CaCO_3 = Total Hardness, mg/l as CaCO_3 – Total Alkalinity, mg/l as CaCO_3

### Lime / Soda Ash Softening

*Note: If hydrated lime (Ca(OH)_2) is used instead of quicklime (CaO), substitute 74 for 56 in equations below.*

\[ \text{Lime Feed, mg/L} = \frac{(A + B + C + D) (1.15)}{\text{Purity of Lime, as a decimal}} \]

A = Carbon dioxide (CO_2) in source water: \( \text{mg/l as CO}_2 \times (56/44) \)

B = Bicarbonate alkalinity removed in softening: \( \text{source water, mg/l as CaCO}_3 \times \text{softened water, mg/l as CaCO}_3 \times (56/100) \)

C = Hydroxide alkalinity in softener effluent: \( \text{mg/l as CaCO}_3 \times (56/100) \)

D = Magnesium removed in softening: \( \text{source water Mg}^{2+}, \text{mg/l} \times \text{softened water Mg}^{2+}, \text{mg/l} \times (56/24.3) \)

Excess Lime, mg/l = \( (A + B + C + D) (0.15) \)

Soda Ash, dosage to remove noncarbonated hardness:
\[ \text{Soda Ash (Na}_2\text{CO}_3 \text{) Feed, mg/l} = (\text{Noncarbonate Hardness, mg/l as CaCO}_3) (106/100) \]

Carbon Dioxide, dosage to recarbonate:
\[ \text{Total CO}_2 \text{ Feed, mg/l} = \text{(excess lime, mg/l)} \times 44/56 + \text{(Mg}^{2+} \text{ residual, mg/l)} \times 44/58.3 \]

Lime Feeder Setting, lbs/day = \( \text{(Flow, MGD) (Dose, mg/l) (8.34 lbs/gal)} \)

Feed Rate, lbs/min = \[ \frac{\text{Feeder Setting, lbs/day}}{1,440 \text{ min/day}} \]
Ion Exchange Softening

Hardness, grains/gallon = \[
\frac{(\text{Hardness, mg/l}) \cdot (1 \text{ grain/gallon})}{17.1 \text{ mg/l}}
\]

Exchange Capacity, grains = (Media Volume, cu ft) \cdot (Removal Capacity, grains/cu ft)

Water Treated, gal = \[
\frac{\text{Exchange capacity, grains}}{\text{Hardness Removed, grains/gallon}}
\]

Unit Operating Time, hrs = \[
\frac{\text{Water Treated, gallons}}{(\text{Avg Daily Flow, gpm}) \cdot (60 \text{ min/hr})}
\]

Bypass Flow, gpd = \[
\frac{\text{Total Flow, gpd} \cdot (\text{Desired Finished Water Hardness, gpg})}{\text{Source Water Hardness, gpg}}
\]

Bypass Water, gals = \[
\frac{\text{(Softener Capacity, gal)} \cdot \text{(Bypass Flow, gpd)}}{\text{Softener Flow, gpd}}
\]

Total Flow, gallons = \text{Softener Capacity, gal} + \text{Bypass Water, gal}

Temperature Conversions

Degrees Celsius, °C = \[
\frac{(^\circ\text{F} - 32)}{1.8}
\]

Degrees Fahrenheit, °F = \[
(^\circ\text{C} \cdot 1.8) + 32
\]

Turbidity

Removal Percentage, % = \[
\frac{(\text{Influent Turbidity} - \text{Effluent Turbidity})}{\text{Influent Turbidity}} \times 100\%
\]

Water Loss

Unaccounted For Water, % = \[
\frac{(\text{Water Produced, gals} - \text{Water Billed, gals})}{\text{Water Produced, gals}} \times 100\%
\]

Water Production

Gallons per Capita/Day = \[
\frac{\text{Volume of Water Produced, gpd}}{\text{Population Served}}
\]

Water Treatment Plant % capacity

Capacity, % = \[
\frac{\text{Average Daily Flow, MGD}}{\text{Plant Design Capacity, MGD}} \times 100\%
\]
### Abbreviations:

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Definition</th>
<th>Unit</th>
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<tr>
<td>cfs</td>
<td>Cubic feet per second</td>
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</tr>
<tr>
<td>DO</td>
<td>Dissolved oxygen</td>
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</tr>
<tr>
<td>ft</td>
<td>Feet</td>
<td>mg/L</td>
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<tr>
<td>fps</td>
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Abbreviations:
- cfs: Cubic feet per second
- DO: Dissolved oxygen
- ft: Feet
- fps: Feet per second
- GFD: Gallons per day per square foot
- gm: Grams
- gpd: Gallons per day
- gpg: Grains per gallon
- gpm: Gallons per minute
- gph: Gallons per hour
- gr: Grains
- hp: Horsepower
- in: Inch
- kg: Kilogram
- kW: Kilowatt
- kWh: Kilowatt-hour
- m: Meter
- mg: Milligrams
- mg/L: Milligrams per liter
- lbs: Pounds
- MGD: Million gallons per day
- mL: Milliliter
- ppb: Parts per billion
- ppm: Parts per million
- psi: Pounds per square inch
- Q: Flow
- SS: Settleable solids
- TTHM: Total trihalomethanes
- TOC: Total organic carbon
- TSS: Total suspended solids
- VS: Volatile solids
- W: Watt