SECTION - 3
KEY WATER PLANT MATH FORMULAS

General:

1. **Lbs/Day** = (Vol, MGD) x (Conc., mg/l) x 8.34 lbs/gal)

2. **Dosage, mg/l** = $\dfrac{(\text{Feed, lbs/day})}{(\text{Vol, MGD}) \times 8.34 \text{ lbs/gal})}$

3. **Rectangular Basin Volume, cu. ft.** = (Length, ft) x (Width, ft) x (Height, ft)

   i) **Vol, Gals** = Multiply the above by the factor 7.48 gals/cu.ft.

4. **Right Cylinder Volume, cu. ft.** = (0.785) x (D^2, ft.) x (Height or Depth,ft)

   i) **Vol, Gals** = Multiply the above by the factor 7.48 gals/cu.ft.

5. **Conical Base Volume, cu. ft.** = $\dfrac{(0.785) \times (D^2,\text{ft}) \times (\text{Height or Depth,ft})}{3}$

   i) **Vol, Gals** = Multiply the above by the factor 7.48 gals/cu.ft.

6. **Trapezoid, Volume cu. ft.** = $\dfrac{(B_1 + B_2)}{2}$ x Height, ft x Length, ft.

   i) **Vol, Gals** = Multiply the above by the factor 7.48 gals/cu.ft.

7. **Removal, Percent** = $\dfrac{(\text{In - Out})}{\text{In}}$ x 100

8. **Decimal Fraction** = $\dfrac{(\text{Percent})}{100}$

GPCD **means** **Gallons Per Capita Per Day. A Capita is one (1) person.**

9. **Gals/Day of Water Consumption, (Demand/Day)** **=** **(Population) x (Gals/Capita/Day)**

Consumption Averages, per capita:

1. **Winter - 170 GPCD**
2. **Spring - 225 GPCD**
3. **Summer - 325 GPCD**

10. **Gals/Capita/Day, Average Water Usage** **=** $\dfrac{\text{(Vol, Gals/day)}}{\text{(Population, Served per day)}}$

11. **Supply, Days (Full to Tank Dry)** **=** $\dfrac{\text{(Vol, Gals/day)}}{\text{(Population Served) x (GPCD)}}$

12. **GPD** **=** $\dfrac{\text{(Meter Read 2, Gals - Meter Read 1, Gals)}}{\text{(Number of Days)}}$

13. **GPH** **=** $\dfrac{\text{(Volume, gallons)}}{\text{(Pumping Time, min. x 60 Min/Hr)}}$

14. **Time, Hrs.** **=** $\dfrac{\text{(Volume, gallons)}}{\text{(Pumping Rate, GPM x 60 Min/Hr)}}$

15. **Supply, Hrs. (Full to Tank Dry)** **=** $\dfrac{\text{(Storage Volume, Gals)}}{\text{(Flow In, GPM - Flow Out, GPM) x 60 min/hr.}}$

16. **GPD Combined Consumption** **=** **(Pump In, GPD) + (Clearwell Storage Volume, GPD Used)**

17. **Percent (%) of Increase** **=** $\dfrac{\text{(Larger Amount)}}{\text{(Smaller Amount)}} - 1.0 \times 100$

Chlorine Feed, Dosage/Demand/Residual:

Gas Chlorine Feed, Lbs/day

1. Lbs/Day = (Vol, MGD) x (Conc., mg/l) x (8.34 lbs/gal)

$$\text{Dosage, mg/l} = \frac{(\text{Lbs/day})}{(\text{MGD}) \times (8.34 \text{ lbs/gal})}$$

65% HTH Feed, Lbs/day - Calcium Hypochlorite

2.
$$\text{HTH, lbs/Day} = \frac{(\text{Vol, MGD}) \times (\text{Conc., mg/l}) \times (8.34 \text{ lbs/gal})}{(0.65)}$$

$$\text{Dosage, mg/l} = \frac{(\text{Lbs/day} \times 0.65)}{(\text{MGD}) \times (8.34 \text{ lbs/gal})}$$

$$\text{Lbs, 65\% HTH} = \frac{(\text{Gals of Water} \times 8.34 \text{ lbs/gal}) \times \% \text{ Solution}}{(0.65)}$$

5-1/4% - 12.5% Liquid Chlorine - Sodium Hypochlorite

3.
$$\text{Lbs/Gal} = \frac{(\text{Solution Percentage})}{100} \times 8.34 \text{ lbs/gal} \times \text{S.G.}$$

$$\text{GPD} = \frac{(\text{Vol, MGD}) \times (\text{Conc., mg/l}) \times (8.34 \text{ lbs/gal})}{(\text{Lbs/gal})}$$

Dosage/Demand/Residual

4. Dosage, mg/l = (Demand, mg/l) + (Residual, mg/l)
5. Demand, mg/l = (Dosage, mg/l) - (Residual, mg/l)
6. Residual, mg/l = (Dosage, mg/l) - (Demand, mg/l)

MATH FORMULAS - Continued

C●t Calculations

1. **C●t = (Chlorine Residual, mg/L) x (Time, minutes**

2. **Time, minutes** $= \dfrac{(\text{C●t})}{(\text{Chlorine Residual, mg/L})}$

3. **Chlorine Residual, mg/L** $= \dfrac{(\text{C●t})}{(\text{Time, minutes})}$

4. Inactivation Ratio $= \dfrac{(\text{Actual System C●t})}{(\text{Table "E" C●t})}$

5. **C●t Calculated** = T_{10} **Value, minutes x Chlorine Residual, mg/L**

6. Log Removal $= \left(1.0 - \dfrac{\%\ \text{Removal}}{100}\right)$ x **Log key x (-)**

SECTION 3 - SUMMARY OF KEY WATER PLANT OPERATOR MATH FORMULAS - Continued

Fluoridation:

1. Feed, Lbs/day =

$$\text{Feed, Lbs/day} = (\text{MGD}) \times \frac{(\text{mg/L})}{\left(\frac{\%\ \text{Purity}}{100} \times \frac{\%\ \text{Fluoride}}{100}\right)} \times 8.34\ \text{lbs/gallon} \times \text{S.G.}$$

2. Adjusted Feed, Lbs/day =

$$\text{Adjusted Feed, Lbs/day} = (\text{MGD}) \times \frac{(\text{Desired, mg/L} - \text{Existing mg/L})}{\left(\frac{\%\ \text{Purity}}{100} \times \frac{\%\ \text{Fluoride}}{100}\right)} \times 8.34\ \text{lbs/gallon} \times \text{S.G.}$$

3. Dosage, mg/L =

$$\text{Dosage, mg/L} = \frac{\left(\text{Feed, Lbs/day} \times \frac{\%\ \text{Purity}}{100} \times \frac{\%\ \text{Fluoride}}{100}\right)}{(\text{MGD}) \times 8.34\ \text{lbs/gallon} \times \text{S.G.}}$$

SECTION 3 - SUMMARY OF KEY WATER PLANT OPERATOR MATH FORMULAS - Continued

1. Hydraulic (Water Column Height) Pressure :

i) $$\text{PSI} = \frac{(\text{Head, ft.})}{2.31\ \text{ft./PSI}}$$

ii) $$\text{PSI} = \text{Head, ft.} \times 0.433\ \text{PSI/ft.}$$

Or,

iii) $$\text{Head, ft.} = \text{PSI} \times 2.31\ \text{ft./PSI}$$

iv) $$\text{Head, ft} = \frac{\text{PSI}}{0.433\ \text{PSI/ft.}}$$

Pounds of Force On The Face of a Valve

2) Force, lbs = (Area, Sq. Inches) x PSI,

Or,

3) $$\text{Force, lbs} = (0.785)(\text{D, ft.})^2 \times 144\ \text{sq.in/sq.ft.} \times \text{PSI.}$$

Tank Bottom Force and Buoyancy

Tank Bottom Forces:

Rectangular Basins

4) $$\text{Force, lbs} = \text{L, ft} \times \text{W,ft,} \times \text{H, ft,} \times 62.4\ \text{lbs/cubic foot}$$

Right Cylinders

5) $$\text{Force, lbs} = (0.785)(\text{D, ft.})^2 \times \text{Height, ft.} \times 62.4\ \text{lbs/cu.ft.}$$

Pounds Per Square Foot on a Tank Bottom:

Rectangular Basins

6) $$\text{Force, lbs} = \frac{\text{L, ft} \times \text{W,ft,} \times \text{H, ft,} \times 62.4\ \text{lbs/cubic foot}}{(\text{Bottom Area, sq. ft.})}$$

Right Cylinders

7) $$\text{Force, lbs} = \frac{(0.785)(\text{D, ft.})^2 \times \text{Height, ft.} \times 62.4\ \text{lbs/cu.ft.}}{(\text{Bottom Area, sq. ft.})}$$

Change of Direction

8. Force, lbs (Any Bend) = $2 \times [\text{Area}_{\text{sq.in.}} \times \text{Pressure}_{\text{, Psi}}] \times (1/2 \sin \Theta)$

SECTION 3 - SUMMARY OF KEY WATER PLANT OPERATOR MATH FORMULAS - Continued

Pumps and Pumping:

1. **Pumping Rate:**

Volume, Gals $= \text{GPM} \times \text{Time, minutes}$

Rate, GPM $= \dfrac{(\text{Tank Volume, Gals})}{(\text{Time, minutes})}$

Time, minutes $= \dfrac{(\text{Tank Volume, Gals})}{(\text{Fill Rate, GPM})}$

2. **Pump Size:**

Water Horsepower $= \dfrac{(\text{GPM}) \times (\text{Total Head, ft})}{(3{,}960)}$

Brake Horsepower $= \dfrac{(\text{GPM}) \times (\text{Total Head, ft})}{(3{,}960) \times (\%\ \text{Efficiency})}$

% Overall Effic. (Pump/Motor) $= (\text{Motor, \% Effic.} \times \text{Pump \% Effic.})$

3. **Pumping Cost:**

Cost, $ $= (\text{BHp}) \times (0.746\ \text{Kw/Hp}) \times (\text{Operating Hrs.}) \times \dfrac{¢/\text{Kw-Hr.}}{100}$

4. **Wells:**

Drawdown, ft. $= \text{Pumping Level, ft.} - \text{Static Level, ft.}$

Specific Capacity, GPM/ft. $= \dfrac{\text{Well Yield, GPM}}{\text{Drawdown, ft.}}$

SECTION 3 - SUMMARY OF KEY WATER PLANT OPERATOR MATH FORMULAS - Continued

Strength of Solutions:

1. **Chemical Feed Pumps:**

$$\textbf{GPD (Gals)} = \frac{(\text{Required Feed, Lbs/Day})}{(\text{Dry lbs/Gal})} = \frac{(\text{MGD}) \times \text{mg/L} \times 8.34 \text{ lbs/gal}}{(\text{Dry Lbs/gal})}$$

2. **Chemical Feed Rate:**

$$\textbf{GPD} = \frac{(\textbf{Feed, ml/min.} \times 1{,}440 \text{ min/day})}{(1{,}000 \text{ ml/L} \times 3.785 \text{ L/Gal})}$$

$$\text{GPM} = \frac{(\text{Feed, ml/min})}{(3{,}785 \text{ ml/Gal})}$$

$$\textbf{ml/min} = \frac{(\textbf{GPD} \times 1{,}000 \text{ ml/L} \times 3.785 \text{ L/Gal})}{(1{,}440 \text{ min/day})}$$

$$\text{ml/min} = (\text{GPM} \times 3{,}785 \text{ ml/Gal})$$

3. Lbs/gallon $= \frac{(\% \text{ Solution})}{(100)} \times 8.34 \text{ lbs/gallon} \times (\text{Specific Gravity})$

4. Lbs Chemical = Specific Gravity x 8.34 lbs/gallons x Gallons of Solution

5. Specific Gravity $= \frac{(8.34 \text{ lbs/gallon} + \text{Chemical Wt., Lbs/gallon})}{(8.34 \text{ lbs/gallon})}$

6. Specific Gravity, Lbs/gallon = (S.G. x 8.34 lbs/gal) - (8.34 lbs/gal)

7. % Percent of Chemical in Solution $= \frac{(\text{Dry Chemical, Lbs})}{(\text{Dry Wt. Chemical, Lbs}) + (\text{Water, Lbs})} \times 100$

8. Two-Normal Equations:
   a) $\mathbf{C_1V_1 = C_2V_2}$ b) $\mathbf{\frac{Q_1}{V_1} = \frac{Q_2}{V_2}}$

9. Three Normal equations:
   a) $\mathbf{(C_1 V_1) + (C_2 V_2) = (C_3 V_3)}$

SECTION 3 - SUMMARY OF KEY WATER PLANT OPERATOR MATH FORMULAS - Continued

Sedimentation Tanks and Clarifiers:

Hydraulic Cross-check Formulas:

1. **Surface Loading Rate, GPD/sq ft.** = $\dfrac{\text{Total Flow, GPD}}{\text{Surface Area, sq.ft.}}$
   Design Data: 800 - 1,200 GPD/Sq.ft.

2. **Detention Time, Hrs.** = $\dfrac{(\text{Volume, gals}) \times (\text{24 Hrs./day})}{\text{Total 24 Hr. Flow, Gals/day}}$
   Design Data: 1 - 4 Hours; Average 2.5 Hrs.

3. **Flow, GPD** = $\dfrac{(\text{Volume, gals}) \times (\text{24 Hrs./day})}{\text{Detention Time, Hrs.}}$

4. **Weir Overflow Rate, GPD/L.F.** = $\dfrac{\text{Flow, GPD}}{\text{Weir length, ft.}}$
   Design Data: 10,000 - 40,000 GPD/LF; Average 20,000 GPD/L.F.

5. Circumference, ft = 3.141 (Pi) x Diameter, ft.

6. Solids Loading Rate, lbs/day/sq. ft. = $\dfrac{\text{Solids into Clarifier, lbs/day}}{\text{Surface Area, sq. ft.}}$

7. Sludge Solids, lbs = (Flow, Gals) x (8.34 lbs/gal) x (Sludge, %)

8. Raw Sludge Pumping, gpm = $\dfrac{(\text{Settleable Solids, ml/L}) \times (\text{Plant Flow, GPM})}{\text{1,000 mls/L}}$

9. Sludge Volume Index, mg/l (SVI) = $\dfrac{(\text{Settled Sludge Volume, ml/l}) \times (\text{1,000 mg/G})}{\text{Suspended Matter, mg/l}}$

10. mg/l = $\dfrac{\text{ml} \times 1{,}000{,}000}{\text{ml sample}}$

Filtration:

1. **Filter Flow Rate:**

   Filtration Rate, GPM = (Filter Area, sq.ft.) x (GPM/sq.ft.)

2. **Filtration Rate, GPM/sq.ft. = $\dfrac{\text{(Flow Rate, GPM)}}{\text{(Filter Area, sq.ft.)}}$**

3. **Filtration Rate Rate, GPD = (Filter Area,sq.ft.) x (GPM/sq.ft.) x 1,440 min/day**

4. **Backwash Rate:**

   Backwash Pumping Rate, GPM = (Filter Area,sq.ft.) x (Backwash Rate, GPM/sq.ft.)

5. Backwash Volume, Gallons = (Filter Area,sq.ft.) x (Backwash Rate, gpm/sq.ft.) x (Time, min).

6. Backwash Rate, GPM/sq.ft. = $\dfrac{\text{(Backwash Volume, gpm)}}{\text{(Filter Area, sq.ft.)}}$

7. Backwash, GPM = (Filter Area, sq.ft.) x (Height, Rise/Fall/Drop, ft/min) x (7.48 gals/cu.ft.)

8. Rate of Rise, GPM/Sq. Ft. = (Height, Rise/Fall/Drop, ft/min) x (7.48 gals/cu.ft.)

9. Rate of Rise, GPM/sq.ft. = (Time, min) x (Height, ft.) x 7.48 gals/cu.ft.

SECTION 3 - SUMMARY OF KEY WATER PLANT OPERATOR MATH FORMULAS - Continued

Velocity:

1. **Q, cfs** = **(Area, sq. ft.) x (Velocity, fps)**

   $$\frac{(\text{GPM})}{(448.8\ \text{GPM/cfs})} = (0.785) \times (\text{D, ft})^2 \times \frac{(\text{Distance, ft.})}{(\text{Time, seconds})}$$

2. **Velocity. fps** = $\frac{(\text{Q, cfs})}{(\text{Area, sq. ft.})}$

3. **Area, sq. ft.** = $\frac{(\text{Q, cfs})}{(\text{Velocity, fps})}$

4. Flow Conversions:

   Flow, GPM = (Q, cfs) x (448.8 GPM/cfs)

5. Q, Cfs = $\frac{(\text{Flow, GPM})}{(448.8\ \text{GPM/cfs})}$

6. Pipe Diameter, Inches = $\sqrt{\frac{(\text{Area, sq.ft.})}{(0.785)}} \times 12$ inches/ft

7. Actual Leakage, GPD/Mile-inch = $\frac{\textbf{Leak Rate, GPD}}{\textbf{(Length, Mile) x (Diameter, inch)}}$

Note: **Minimum Flushing Velocity:** **2.5 FPS**
Maximum Pipe Velocity: **5.0 FPS**

Key Conversions: **1.55 cfs/mgd** **448.8 GPM/cfs**

Headloss Due to Friction:

1. **Darcy-Weisbach:**

$$\text{Headloss, ft} = (f)\ \frac{L,_{ft} \times V^2}{D,_{ft} \times 2g} \quad \text{(Use the Moody Diagram for "f")}$$

2. **Hazen - Williams**

$$Q,\ \text{gpm} = 0.28 \times C \times D^{2.63} \times S^{0.54}$$

$$\text{"C" Factor} = \frac{\text{Flow, gpm}}{193.75\ (D,\text{ft})^{2.63} \times (\text{Slope})^{0.54}}$$

$$\text{HL}/1{,}000\ \text{ft.} = \left(\frac{147.85 \times \text{GPM}}{C \times d^{2.63}}\right)^{1.852}$$

$$V,_{fps} = 1.32 \times C \times R^{0.63} \left(\frac{H}{L}\right)^{0.54}$$

3. **Manning**

$$C,\ \text{cfs} = \frac{1.49}{n} AR^{2/3} S^{1/2}$$

$$\text{Slope} = \left[\frac{\text{CFS} \times n}{1.49 \times A R^{2/3}}\right]^2$$

Ion Exchange:

1. **Calcium Hardness as mg/l $CaCO_3$ = (2.5) x (Calcium, mg/l)**

2. **Magnesium Hardness as mg/l $CaCO_3$ = (4.1) x (Magnesium, mg/l)**

3. **Total Hardness = Calcium + Magnesium Hardness as $CaCO_3$.**

4. **Convert Hardness from mg/l to grains/gallon:**

$$\textbf{Grains/gallon} = \frac{\textbf{(Total Hardness, mg/l)}}{\textbf{(17.1 mg/l/Grain}}$$

5. Total Exchange Capacity, Kilograins = (Resin Cap., kilograins/cu.ft.) x (Vol, cu.ft.)

6. Total Grains Capacity = Kilograins x 1,000

7. Gals of Soft Water per Service Run

$$= \frac{\text{(Total Exchange Capacity x Kilograins x 1,000)}}{\text{(Total Hardness as } CaCO_3\text{, Grains/gallon)}}$$

8. By-Pass Water, GPD

$$= \frac{\text{(Flow, GPD) x (Effluent Hardness, Gr/Gal)}}{\text{(Influent Hardness, Gr/Gal)}}$$

9. By-Pass Water, %

$$= \frac{\text{(Discharge Hardness, mg/l)}}{\text{(Initial Hardness, mg/l)}} \times 100$$

Ion Exchange Formulas
(Continued)

10\. Salt, lbs $= \dfrac{(\text{Capacity, Grains}) \times (\text{Salt, lbs})}{(1{,}000 \text{ Grains})}$

11\. Brine, Gals $= \dfrac{(\text{Salt Needed, lbs})}{(\text{Salt, lbs/gallon})}$

12\. Hardness Removed, Grains $= \dfrac{(\text{Influent Hardness, mg/l} - \text{Effluent Hardness, mg/l})}{(17.1 \text{ mg/L/Grain})}$

13\. % of Soft Water By-pass $= \dfrac{(\text{Blended Discharge Hardness, mg/L})}{(\text{Initial Hardness, mg/L})} \times 100$

14\. GPM By-Pass $= \dfrac{(\text{\% By-Pass})}{100} \times (\text{Total Flow, GPM})$

15\. Total Flow Thru Softener, GPM $= (\text{Total Flow, GPM}) - (\text{By-Pass Flow, GPM})$

Lime - Soda Ash Softening

16\. Lbs Hardness Removed $= (\text{MGD}) \times (\text{Dosage, mg/L}) \times \dfrac{(\text{Soda Ash - Mol Wt.})}{(\text{Calcium Carbonate Mol. Wt.})} \times 8.34 \text{ lbs/gal}$

SECTION 3 - SUMMARY OF KEY WATER PLANT OPERATOR MATH FORMULAS - Continued

Jar Testing:

1. Dosage, mg/l $= \dfrac{\text{(Stock, ml) x 1,000 mg/gram x (Conc., Grams/L)}}{\text{(Sample Size, ml)}}$

2. Grams/Liter $= \dfrac{\text{(mg/l x 1,000 ml)}}{\text{(ml x 1,000 mg/l)}}$

3. **Alum Reacting, mg/l** $= \dfrac{\text{(1.0 mg/l Alum) x (Raw Alk., mg/l - Alk. Present, mg/l)}}{\text{(0.45 mg/l Alkalinity)}}$

4. Alkalinity Dosage, mg/l = (Total Alum, mg/l - Alum Reacting, mg/l)

5. Dilute Solution, mg/L $= \dfrac{\text{(mg of Alum dosage) x (1,000 ml/L)}}{\text{(1.0 ml/L)}}$

6. Grams $= \dfrac{\text{(mg) x (1.0 gram)}}{\text{(1,000 mg/l)}}$

7. mg/L $= \dfrac{\text{(Grams x 1,000 mg/L)}}{\text{(1.0 gram)}}$

SECTION 3 - SUMMARY OF KEY WATER PLANT OPERATOR MATH FORMULAS - Continued

Laboratory:

1. TSS (mg/l) $= \dfrac{\text{Paper Wt. and Dried Solids(g) - Paper Wt.(g)}}{(\text{ Milliliters [ml] of Sample })} \times 1{,}000{,}000$

2. Total Solids, mg/l $= \dfrac{(\text{ Residue, mg }) \times 1{,}000}{(\text{ ml sample })}$

3. Total Alkalinity, Mg/l $= \dfrac{(\text{ mls of titrant x Normality x } 50{,}000\text{ })}{(\text{ mls of Sample })}$

4. Langelier Index = (pH - pH, Saturated)

5. Concentrations:

   (Conc. 1) x (Volume 1) = (Conc. 2) x (Volume 2)

6. mg/l $= \dfrac{(\text{ ml x } 1{,}000{,}000\text{ })}{(\text{ ml sample })}$

   mg/l = ml x 1,000 ml/L

7. mg/l Total Solids $= \dfrac{(\text{ Residue, mg }) \times 1{,}000}{(\text{ ml sample })}$

8. Temperature:

   $F^\circ = (C^\circ \times 1.8) + 32^\circ$

   $C^\circ = \dfrac{(F^\circ - 32^\circ)}{(1.8)}$

ABBREVIATIONS

Ac-ft	Acre feet	M	Meter
AFC	Actual fluoride content	M	Mile
C°	Celsius	mg/l	Milligram per Liter
CCF	Hundred Cubic Feet	MGD	Million Gals/Day
Cf	Cubic feet (ft^3)	ml	Milliliter
CFS	Cubic Feet Per Second	msl	Mean Sea Level
F°	Fahrenheit	ppm	Parts per Million
Gal	Gallon(s)	Q	Flow, cu. ft/sec.
GPM	Gallons Per Minute	π	Pi (3.141)
GPD	Gallons Per Day	Sq. ft.	Square feet (ft^2)
GPH	Gallons Per Hour	Sq. Yd	Square Yards (ft^3)
GPCD	Gallons per capita per day	SWD	Side Wall Depth
H	Height	μ g/L	Microgram/Liter
Hp	Horsepower	V	Velocity
BHp	Brake Horsepower	V	Volume
Whp	Water Horse power		
KW-Hrs	Kilowatt hours		
Lbs	Pounds		
Lbs/Day	Pounds per day		
L	Liter		

END

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