

# Equations and Constants

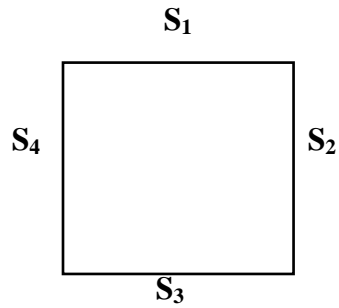
## TABLE OF CONTENTS

A.	FORMULAS	
	Perimeter/Circumference .....	2
	Area .....	3
	Volume .....	4
	Temperature .....	5
	Velocity .....	5
	Flow/Pumping Rate .....	5
	Loading/Pounds.....	6
	Solids.....	6
	Tanks & Clarifiers.....	6
	Filters and Recirculation .....	7
	Collection .....	8
	Other Formulas and Constants .....	10
B.	CONVERSION FACTORS	
	Length.....	2
	Area .....	3
	Volume .....	4
	Flow .....	5
	Weight .....	6
	Master List.....	13
C.	SYMBOLS AND ABBREVIATIONS .....	11
D.	METRIC SYSTEM.....	12

## PERIMETER/CIRCUMFERENCE

1. Rectangle or Square:

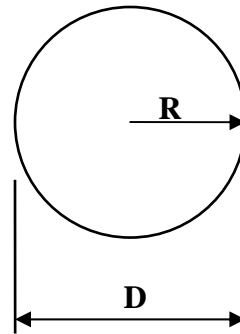
$$P = S_1 + S_2 + S_3 + S_4$$



2. Circle:

$$C = \pi \times D$$

Where:  $\pi = 3.14$   
 $D = 2 \times R$



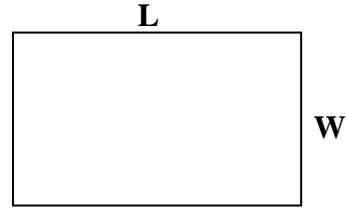
## LENGTH CONVERSION FACTORS

1 inch	=	2.54 centimeters	=	25.4 millimeters
1 foot	=	12 inches	=	0.31 meters
1 yard	=	3 feet	=	0.91 meters
1 mile	=	5,280 feet	=	1,760 yards
1 meter	=	39.37 inches	=	3.28 feet
1 kilometer	=	0.62 miles	=	1,000 meters

## AREA

1. Square or Rectangle:

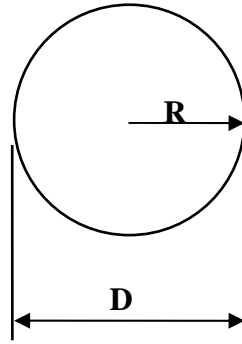
$$A = L \times W$$



2. Circle:

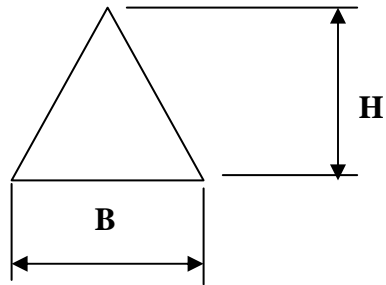
$$A = \pi \times R^2$$

Where:  $D = 2 \times R$



3. Triangle:

$$A = \frac{B \times H}{2}$$



## AREA CONVERSION FACTORS

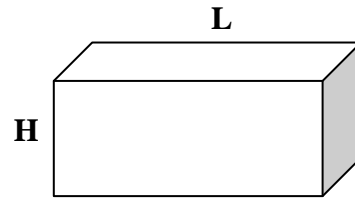
1 square foot	=	144 square inches
1 square yard	=	9 square feet
1 square mile	=	640 acres or 1 section
1 square meter	=	10.76 square feet
1 square meter	=	10,000 square centimeters
1 acre	=	43,560 square feet
1 hectare	=	2.47 acres

## VOLUME

1. Rectangle

$$\text{Volume} = \text{Area} \times \text{Height}$$

$$V = L \times W \times H$$



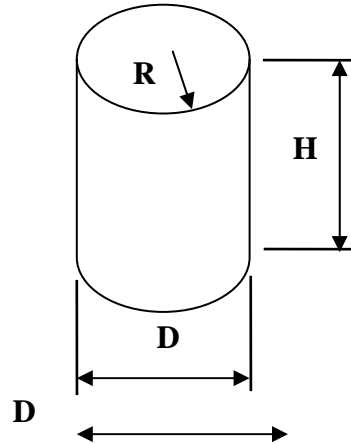
W

2. Cylinder:

$$\text{Volume} = \text{Area} \times \text{Height}$$

$$V = \pi \times R^2 \times H$$

Where :  $D = 2 \times R$



### VOLUME CONVERSION FACTORS

1 cubic foot	=	1,728 cubic inches
1 cubic foot	=	7.48 gallons
1 cubic yard	=	27 cubic feet
1 acre-inch	=	27,152 gallons
1 acre-foot	=	43,560 cubic feet
1 acre-foot	=	326,000 gallons
1 gallon	=	3.79 liters
1 gallon	=	231 cubic inches
1 gallon	=	4 quarts
1 cubic meter	=	35.3 cubic feet
1 cubic meter	=	1.3 cubic yards
1 liter	=	0.26 gallons
1 liter	=	1,000 milliliters

## TEMPERATURE

1. Fahrenheit to Celsius:

$$^{\circ}\text{C} = \frac{5(^{\circ}\text{F} - 32)}{9}$$

2. Celsius to Fahrenheit:

$$^{\circ}\text{F} = \frac{(^{\circ}\text{C} \times 9)}{5} + 32$$

## VELOCITY

1. Velocity =  $\frac{\text{distance traveled}}{\text{time}}$

2. Velocity(C) =  $\frac{\text{flow rate}}{\text{area}} = \frac{Q}{A}$

## FLOW/PUMPING RATE

1. Flow Rate (Q) = velocity (V) x area (A)

2. Pumping Rate =  $\frac{\text{volume pumped}}{\text{time pumped}}$

3. Calibrated Pumping Rate (gallons per minute):

$$= \frac{\text{drawdown volume (gallons)}}{\text{time to drawdown ( minutes)}}$$

$$= \frac{(\text{Reading 1 in inches} - \text{Reading 2 in inches}) \times \text{gallon per inch of tank}}{\text{Time (min)}}$$

## FLOW CONVERSION FACTORS

1 cubic foot/second	=	449 gallons/minute (GPM)
1 gallon/second	=	0.13 cubic feet/second (CFS)
1 gallon/second	=	8.03 cubic feet/minute (CFM)
1 gallon/minute	=	0.002 cubic feet/second (CFS)
1 gallon/minute	=	1440 gallons/day (GPD)

## LOADING and SOLIDS

1. Loading ( lb/day) = concentration ( mg/L) x flow (gallons/day) x 8.34 lb/gallon/1,000,000
2. Organic Loading (lb/day) = population ( people) x population equivalent factor (lb/person/day)

**Note: Population equivalent factors for: BOD = 0.17 lb/person/day  
TSS = 0.20 lb/person/day**

## WEIGHT CONVERSION FACTORS

1 gallon	=	8.34 pounds of water
1 cubic foot	=	62.4 pounds of water
1 foot of water	=	0.433 pounds per square inch
1 pound	=	0.454 kilograms
1 kilogram	=	2.2 pounds
1 kilogram	=	1,000 grams
1 pounds per square inch	=	2.31 feet of water
1 liter	=	1,000 grams
1 mg/kg or 1 ppm or 1 mg/l	=	0.0022 pounds/ton or 0.0001%
1 mg/l	=	1,000 µg/l

3. Total Suspended Solids (mg/L) =  $\frac{\text{weight of suspended solids (mg)}}{\text{volume of sample (liter)}}$
4. Organic Nitrogen = Kjeldahl Nitrogen - Ammonia Nitrogen

## SOILS

1. Percolation rate = min/in
2. Ksat =
3. Contour Loading Rate (CLR) = gal/ft

## TANKS & CLARIFIERS

1. Surface Settling Rate (SSR): 
$$\text{SSR} = \frac{\text{flow rate}}{\text{surface area}}$$
2. Tank capacity in gallons 
$$\text{TC} = \text{L(ft)} \times \text{W (ft)} \times \text{Liquid depth(ft)} \times 7.48 \text{ gal/ft}^3$$
3. Detention Time (DT): 
$$\text{DT} = \frac{\text{volume of tank}}{\text{flow rate to or from tank}}$$
4. Percent Removal (PR): 
$$\text{PR (\%)} = \frac{\text{influent} - \text{effluent}}{\text{influent}} \times 100\%$$

## FILTERS

### 1. Hydraulic Loading Rate (HLR):

$$\text{HLR} = \frac{\text{total flow to filter} *}{\text{surface area of filter}}$$

\* Where total flow = influent flow + recirculation flow

### 2. Organic Loading Rate (OLR): (lbs per day per 1000 cubic feet)

$$\text{OLR} = \frac{\text{pounds per day applied to the filter}}{\text{volume of filter media ( in 1000 cubic feet units)}}$$

## CALCULATING RECIRCULATION RATIOS AT SYSTEM STARTUP

To set recirculation at the time of system startup, the flowing information is needed:

- Forward flow through the system – this will be assumed from available records and/or interviews or design flow
- Pump delivery rate of the pump dosing the media filter (in gallons per minute)
- Dose volume
- Amount of pipe drainback to the pump after a dose
- Desired recirculation ratio, based upon forward flow (usually determined by the designer or manufacturer – 3:1 – 5:1)
- Number of minutes in a day = 1440

Before media filter startup occurs, it is important that the startup person understand how the regulatory jurisdiction and/or manufacturer determines recirculation volume to the filter. Most proprietary technologies use the following basic formula: [(forward flow) multiplied times (desired recirculation)] plus (forward flow) = volume to the filter. Other entities/manufacturers may calculate recirculation differently, for example [(desired recirculation) multiplied by (forward flow)], so always verify before startup.

***For the following example the manufacturer-determined pump dose volume per pump cycle (15 gallons) will not be altered. The pump off time needed to meet the desired recirculation ratio will be determined.***

The following values will be assumed for this example:

- Forward flow = 200 gallons per day (gpd) -made by assumption
- Pump delivery rate (PDR) = 30 gallons per minute (gpm)
- Pump on time = 15 gallons/dose / 30 gpm = 0.5 minutes (min) on
- Pump dose volume = PDR X Pump run time = 30 gpm X 0.5 min = 15 gallons per dose
- No pipe drainback is assumed to simplify this example
- Desired recirculation ratio of 3:1 as required by manufacturer (Using the first formula noted above, the filter surface will see four times the amount of forward flow or [200 gpd x 3] + 200 gpd = 800 gpd

Given the above information, let's calculate what the pump off time needs to be:

Note, that to simplify the example, the entire pump dose volume (15 gallons) reaches the media filter surface with no pipe drainback.

Number of pump dose events needed to meet the 3:1 ratio =  $800 \text{ gpd} \div 15 \text{ gallons per dose event} = 53.3$  dose events per day. **Because we can't have a fraction of a dose event, this is rounded down to 53 events.** Note that for each dose event there is a corresponding pump rest cycle—or 53 rest cycles a day.

Number of minutes per day =  $24 \text{ hours} \times 60 \text{ min per hour} = 1440 \text{ min/day}$

Pump off time (minutes) =  $(\text{number of minutes per day} \div \text{pump rest cycles per day}) \text{ minus pump on time}$ .  
Substituting in numbers, the math is:  $(1440 \text{ min/day} \div 53 \text{ pump rest cycles}) - 0.5 \text{ min} = 26.7 \text{ min}$

**Answer: 26.7 minutes off time between pump doses**

To double check the math, the combined pump on and off times multiplied by the number of dose events per day should equal the total number of minutes in a day (or 1440 minutes).

**Check:**  $(0.5 \text{ min} + 26.67 \text{ min}) \times 53 \text{ dose events} = 27.2 \text{ min} \times 53 \text{ dose events} = 1440 \text{ min}$

To double check the math on the timer settings; multiply the pump on time by the dose events per day, and multiply this number by the pump delivery rate (or PDR). The result should equal the total gallons needed to meet the desired recirculation ratio (or 800 gpd).

**Check:**  $(0.5 \text{ min per dose} \times 53 \text{ dose events/day}) \times 30 \text{ gpm} = 795 \text{ gpd}$

**Note that the answer above is very close to the 800 gpd needed to meet our desired recirculation ratio. The difference is because we could not utilize a portion (0.3) of a dosing event, so earlier in our calculations we decided to round down to 53 dose events per date.**

## COLLECTION

### 1. Flow Rate Equation

$$Q = VA$$

Q = Flow Rate (cubic feet/second)

V = Velocity of flow (feet/sec)

A = Area =  $\pi D^2/4$  or  $0.785 D^2$

D = Diameter (feet)

### 2. Hazen Williams Equation

$$V = 1.318 * C * R^{0.63} * S^{0.54}$$

C = Hazen-Williams Roughness Coefficient

R = Hydraulic Radius (feet)

S = Slope of Energy Grade Line

$R = D/4$

$S = H_f/L$

$H_f$  = Friction head loss (feet)

L = Length of Pipe (feet)

$$H_f = (V/1.318 * C * R^{0.63})^{1.85} * L$$



Multiplier for  $H_f$  in Pump Problem #1 on Page 83 (20.22)

$$H_f = \frac{L}{(1.318 * CAR^{0.63})^{1.8591}} * Q^{1.8591}$$

If V is known

$$H_f = V^{1.8591} * \frac{L}{(1.318CR^{0.63})^{1.8591}}$$

### 3. Manning Equation

$$V = k/n(A/P)^{2/3}S^{1/2} \quad \text{where } k = 1.486, \text{ and } n = 0.013$$

$n = 0.013$  should be used for PVC pipe.

Inserting the constants in the equation:

$$V = 114.3 (A/P)^{2/3}S^{1/2}$$

$$A = \pi D^2/4$$

$$P = \text{Wetted Perimeter (assume full pipe)} = \pi D$$

Simplifying the equation by inserting A and P in terms of D:

$$V = 114.3(D/4)^{2/3}S^{1/2}$$

S = Slope (feet/foot) (usually given, and assumed 1/8 inch per foot, which equates to 0.01 feet/foot)

#### Manning Equation Constants

Pipe Diameter	Velocity (V) ft/s	Area (A) ft <sup>2</sup>	Q <sub>f</sub> (GPM)
4"	2.18	0.087	85.2
6"	2.85	0.197	253.0
8"	3.46	0.349	542.2

#### Other Collection Constants

Minimum slope in pipe = 1/8 inch per 1 foot ~ 1%

Maximum slope in pipe = 0.2 feet/foot = 2%

Maintains velocity below 15 feet/sec

## OTHER FORMULAS

1. Convert Gallons Per Minute to Gallons Per Day:

$$\text{Gallons/day} = \text{gallons/minute} \times 1,440 \text{ minutes/day}$$

3. Percent Removal (%) =  $\frac{\text{influent concentration} - \text{effluent concentration}}{\text{influent concentration}} \times 100\%$

5. Slope or Grade (%) =  $\frac{\text{rise or drop (difference in height)}}{\text{run (difference in length)}} \times 100\%$

## SYMBOLS/ABBREVIATIONS

A	= Area	ml	= milliliters
Ac-Ft	= Acre-feet	MG	= million gallons
B	= Base	MGD	= million gallons per day
BOD	= Biochemical Oxygen Demand	mg/kg	= milligrams per kilogram
C	= Circumference	mg/L	= milligrams per liter
CEC	= Cation Exchange Capacity	MLSS	= mixed liquor suspended solids
CFM	= Cubic Feet per Minute	MLVSS	= mixed liquor volatile suspended solids
CFS	= Cubic Feet per Second	N	= Nitrogen
Cu In.	= Cubic Inches	NH <sub>3</sub> -N	= Ammonia Nitrogen
°C	= Degree Centigrade	Org. N	= Organic Nitrogen
D	= Diameter	P	= Perimeter
Ft	= Foot or Feet	PE	= Population Equivalent
Ft <sup>2</sup>	= Square Feet	ppm	= Parts per Million
Ft <sup>3</sup>	= Cubic Feet	ppb	= Parts per Billion
°F	= Degree Fahrenheit	PSI	= Pounds per Square Inch
F/M	= Food to Mass	Q	= Flow
Gal	= Gallons	R	= Radius
Gal/Min	= Gallons per Minute	RPM	= Revolutions per Minute
Gal/Sec	= Gallons per Second	S	= Side
GPD	= Gallons per Day	Sec	= Second
GPM	= Gallons per Minute	Sq. In.	= Square Inches
GPS	= Gallons per Second	SVI	= Sludge Volume Index
H	= Height	SRT	= Solids Retention Time
hr	= Hour	SS	= Suspended Solids
In.	= Inch	TSS	= Total Suspended Solids
In <sup>2</sup>	= Square Inch	V	= Volume
In <sup>3</sup>	= Cubic Inch	Vel	= Velocity
L	= Length	W	= Width
lb	= Pound	Yd	= Yard
Mi	= Mile	π	= pi or 3.14
Mi <sup>2</sup>	= Square Mile	/	= Per (as gallon/day)
Min	= Minute	%	= Percent
mg	= milligrams	μL	= Microliters

# METRIC SYSTEM

LENGTH	One kilometer (km)	=	1,000 meters
	One meter (m)	=	100 centimeters
	One decimeter (dm)	=	0.1 meter
	One centimeter (cm)	=	0.01 meter
	One millimeter (mm)	=	0.001 meter
WEIGHT	One kilogram (kg)	=	1,000 grams
	One gram (g)	=	1,000 milligrams
	One decigram (dg)	=	0.1 gram
	One centigram (cg)	=	0.01 gram
	One milligram (mg)	=	0.001 gram
VOLUME	One kiloliter (kl)	=	1,000 liters
	One liter (l)	=	1,000 milliliters
	One deciliter (dl)	=	0.1 liter
	One centiliter (cl)	=	0.01 liter
	One mililiter (ml)	=	0.001 liter
AREA	One hectare (HA)	=	10,000 square meters
	One square kilometer	=	1,000,000 square meters

## MASTER LIST - CONVERSION FACTORS

MULTIPLY	BY	TO OBTAIN
Acres	43560	Square Feet
Atmospheres	33.9	Feet of Water
Centimeters	0.40	Inches
Cubic Feet	7.48	Gallons
Cubic Feet	28.32	Liters
Cubic Feet/Second	449	Gallons/Minute
Cubic Meters	35.31	Cubic Feet
Cubic Meters	264.2	Gallons
Cubic Meters	10 <sup>3</sup>	Liters
Cubic Yards	27	Cubic Feet
Cubic Yards	202	Gallons
Feet	30.48	Centimeters
Feet	0.31	Meters
Feet of Water	62.43	Pounds/Square Foot
Feet of Water	0.43	Pounds/Square Inch
Gallons	3785	Cubic Centimeters
Gallons	0.13	Cubic Feet
Gallons	3.79	Liters
Gallons water	8.34	Pounds of Water
Gallons/Minute	2.2 x 10 <sup>-3</sup>	Cubic feet/Second
Gallons/Minute	1440	Gallons/Day
Gallons/ Minute	0.06308	Liters/Second
Gallons/Day	6.9 x 10 <sup>-4</sup>	Gallons/Minute
Gallons/Day/Square Foot	1.604	Inches/Day
Grams	2.21 x 10 <sup>-3</sup>	Pounds
Grams/Liter	1000	Parts/Million
Hectares	2.47	Acres
Horsepower	33,000	Foot-pounds/Minute
Horsepower	0.7457	Kilowatts
Inches	2.54	Centimeters
Inches/Day	0.62	Gallons/Day/Square Foot
Kilograms	2.21	Pounds
Kilowatts	1.34	Horsepower
Kilowatt-hours	2.66 x 10 <sup>6</sup>	Foot-pounds
Liters	103	Cubic Centimeters
Liters	0.04	Cubic Feet
Liters	0.26	Gallons
Meters	3.28	Feet
Milligrams/Liters	1	Parts/Million
Million Gallons/Day	1.55	Cubic Feet/Second
Parts/Million	8.34	Pounds/Million Gallons
Pounds	453.50	Grams
Pounds of Water	0.12	Gallons
Pounds/Square Inch	2.31	Feet of Water
Pounds/Square Inch	2.04	Inches of Mercury
Temperature (°C) + 17.78	1.8	Temperature (°F)
Temp. (°F) - 32	5/9	Temp. (°C)