Conversion Factors and Formulas

ABBREVIATIONS

English

A = area

ac ft. = acre-foot or acre-feet

b = base (of right triangle)

°C = degrees Celsius

cfs or **ft^3/sec** = cubic feet per second

cfm or **ft^3/min** = cubic feet per minute

cfd or **ft^3/day** = cubic feet per day

d = diameter (circle)

°F = degrees Fahrenheit

fps or **ft./sec** = feet per second

ft. = feet

ft^2 or **sq. ft.** = square feet

ft^3 or **cu. ft.** = cubic feet

gpd = gallons per day

gpg = grains per gallon

gpm = gallons per minute

gps = gallons per second

h = height

hrs/day = hours per day

in = inches

in^2 = square inches

in^3 = cubic inches

lbs. = pounds

mi = miles

MG = million gallons

mgd or **MGD** = million gallons per day

ppm = parts per million

ppt = parts per trillion

psi = pounds per square inch

Q = flow

r = radius (circle)

W = watts

A = amps

V = volts

Metric

cm = centimeters

g = gram

Ha = Hectare

kg = kilogram

km = kilometer

kW = kilowatt

L or **l** = liters

m = meter

m^3 = cubic meter

mg = milligram

mg/L or **mg/l** = milligrams per liter or parts per million

mL = milliliter

mm = millimeter

Metric Prefixes

mega (M): x 1,000,000

kilo (k): x 1,000

hecto (h): x 100

deka (da): x 10

deci (d): x 0.10

centi (c): x 0.01

milli (m): x 0.001

micro (μ): x 0.000001

micro to milli: x 0.001

meter: linear measurement

liter: volume measurement

gram: weight measurement

VOLUME

English

1 acre-ft. = 325,828.8 gllons
1 acre-ft. = 43,560 ft^3
1 cfs = 0.646 MGD
1 ft^3 = 7.48 gallons
1 gallon = 231 in^3
1 gallon = 0.1337 ft^3
1 gallon = 3.785 liter
1 gallon = 0.000001 MG
1 MGD = 1.55 cfs
1 MGD = 694gpm

Metric

1 liter = 1,000 mL
1 liter = 0.2642 gallons
1 m^3 = 264.2 gallons
1 m^3 = 35.315 ft^3

AREA

1 acre (ac) = 43,560 ft^2
1 acre = 0.405 Hectare (Ha)
1ft^2 = 144 in^2
1 in^2 = 6.45 cm^2
1yd^3 = 9 ft^2

(metric)
1 hectar = 2.47 acres

FLOW

1 ft^3/sec = 0.6463 MG
1 ft^3/sec = 449 gpm
gpm = 0.00144 MGD
1 MGD = 694.4 gpm
1 MGD = 1.547 cfs
MGD = 3.07 acre-ft/day

WEIGHT & MASS

English	Metric
1 ft^3 water = 62.4 lbs.	1 g = 1,000 m
1 gallon water = 8.34 lbs	1 kg = 1,000 g
1 gpg = 17.118 mg/L	1 mg/L = 0.0584 gpg
1 lb. = 453.6 g	1 kg = 2.2 lbs
	1% = 10,000 mg/L

LENGTH

ENGLISH	Metric
1 foot = 12 in	1 centimeter = 0.3937 in.
1 foot = 0.305 m	1 kilometer = 0.6214 mi
1 inch = 2.54 cm	1 meter = 39.37 in
1 mile = 5,280 ft	1 yard = 3 ft
1 mile = 1.609 km	

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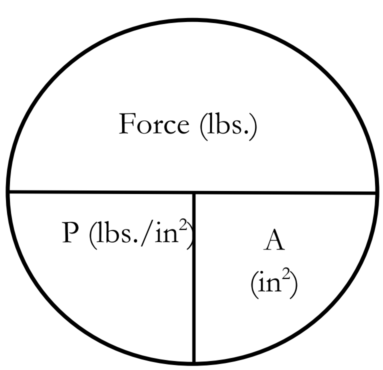
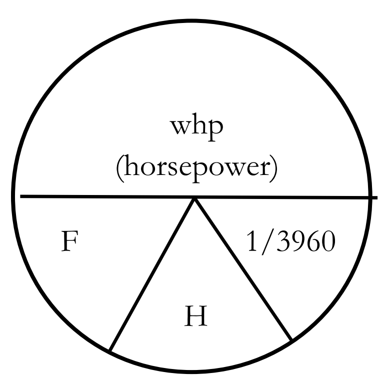
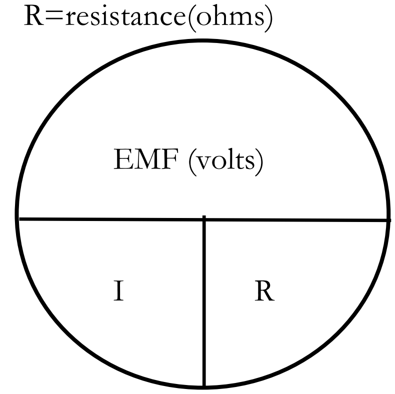
For the operator's convenience, both equation formulas and pie wheel formulas are included in this document. When using the pie wheel formula to solve a problem, multiply together the pie wedges below the horizontal line to solve for the quantity above the horizontal line. To solve for one of the pie wedges below the horizontal line, cover the pie wedge for which you are solving and divide the remaining pie wedge(s) below the horizontal line into the quantity above the horizontal line.

Electromotive Force (EMF) = I x R

WHERE: EMF=electromotive force(volts)
I=current(amps)
R=resistance(ohms)







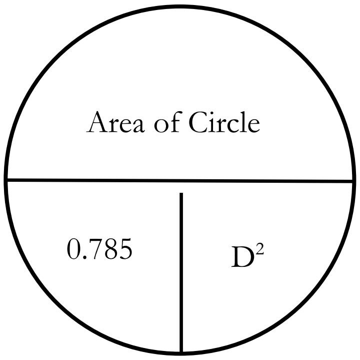
F=(P)x(A)

F=force(lbs)
P=pressure(psi)
A=area(in²)

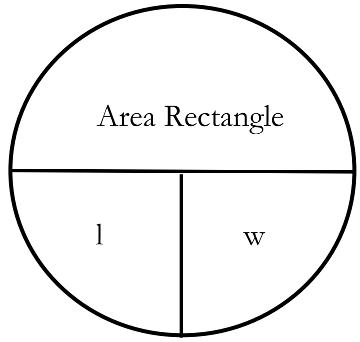
$$whp = \frac{F \times H}{3{,}960}$$

whp = water horsepower
F = flow (gpm)
H = head (ft)

Where: $\pi = 3.1416$
r = radius of circle
D = diameter of circle

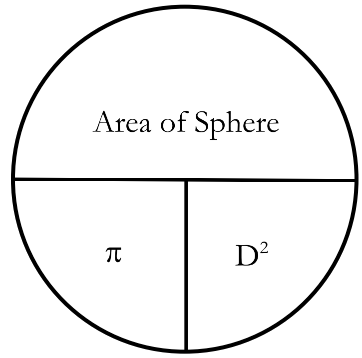


$A = \pi r^2$

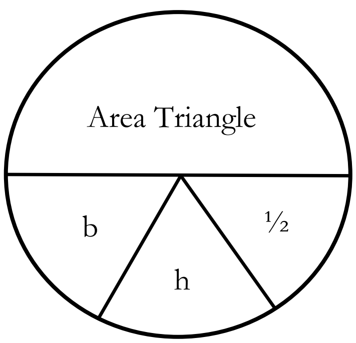


l = length of rectangle

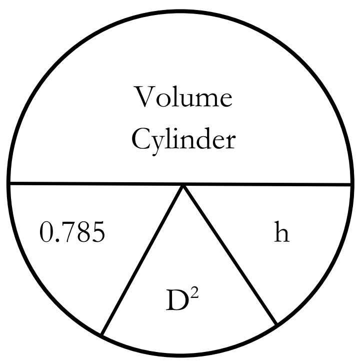
w = width of rectangle



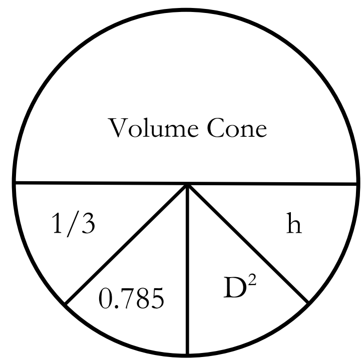
$S = 4\pi r^2$



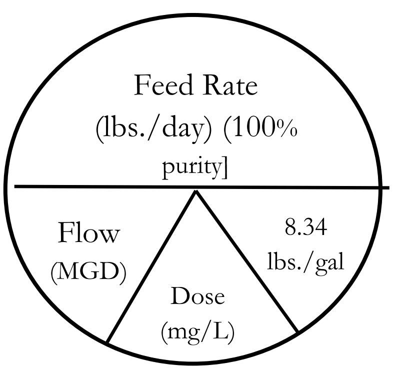
Triangle (area) = [(b) x (h)]/2
b = base of triangle
h = height of triangle

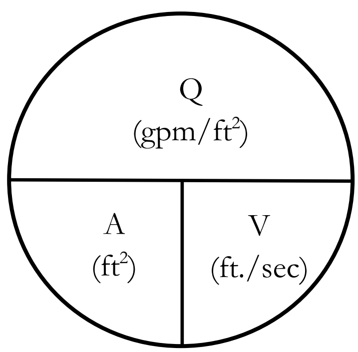


Cylinder = (0.785) x (D^2) x (h)

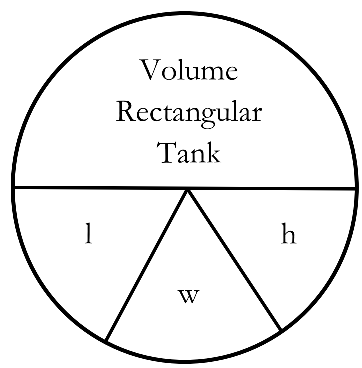


cone = (1/3)x(0.785)x(D^2)x(h)





Q = (A) X (V)



Rectangular Tank = (l) x (w) x (h)

Where:
feed rate = lbs./day
d = dose (mg/L)
Q = flow (MGD)
Chemical purity = %, expressed as decimal

Circumference of Circle

Circumference = $(\pi) \times (D)$

Where: $\pi = 3.1416$
D = diameter of circle

Circumference = $(2) \times (\pi) \times (r)$

Where: $\pi = 3.1416$
r = radius of circle

Flows

$Q = (w) \times (d) \times (V)$

Where: Q = flow in channel (ft^3/sec)
w = width (ft.)
d = depth (ft.)
V = velocity (ft./sec)

$Q = (0.785) \times (D)^2 \times (V)$

Where: Q = flow in full pipe (ft^3/sec)
D = diameter (ft.)
V = velocity (ft./sec)

$Q = \{1.333 \times (h)^2 \times \sqrt{(D/h) - 0.608} \times (V)$

Where: Q = flow in partially full pipe (ft^3/sec)
h = height (ft.)
D = diameter (ft.)
V = velocity (ft./sec)

Q = AV or Q = (Area)(Velocity)

$V = (Q)/ \{(0.785) \times (D)^2\}$

Where: V = velocity (ft./sec)
Q = flow (ft^3/sec)
D = diameter (ft.)

V = (d)/(T)

Where: V = velocity (ft./sec)
d = distance (ft.)
T = time (sec)

$Q = (\sum Q_{daily})/(n_{daily})$

Where: Q = avg. daily flow (MGD)
$\sum Q_{daily}$ = sum all daily flows (MGD)
n_{daily} = number of daily flow

Q = (Water used)/(Population)

Where: Q = daily flow (gal/capita/day)
water used or produced = gal/day
population = total # people served(gpd/ft)

Overflow rate = (Q)/(L)

Where: overflow rate = weir overflow rate
Q = flow (gpd)
L = weir length (ft.)

Change in Velocity = (A1V1) =(A2V2)

Where: A=area
V=velocity

Dosage Formulas

$$\text{Dosage} = \frac{\text{Feed rate}}{(Q) \times (8.34 \text{ lbs./gal})}$$

Where:
dosage = mg/L
feed rate = chemical feed rate (lbs./day)
Q = flow rate (MGD)

$$\text{Dosage} = \frac{(\text{Feed rate}) \times (\text{Purity})}{(Q) \times (8.34 \text{ lbs./gal})}$$

Where:
dosage = mg/L
feed rate = chemical feed rate (lbs./day)
purity = chemical purity, % expressed as decimal
Q = flow rate (gal/min.)

$$\text{Dosage} = \frac{(\text{Feed rate}) \times (1{,}000 \text{ mg/g})}{(Q) \times (3.785 \text{ L/gal})}$$

Where:
dosage = mg/L
feed rate = chemical feed rate(lbs./day)
Q = flow rate (gal/min.)

Dose = Demand + Residual

Chemical Feed/Feed Rate Formulas (lbs.)

$$\text{Chemical feed} = (d) \times (V) \times (8.34 \text{ lbs./gal})$$

Where:
chemical fee = lbs.
d = dose (mg/L)
V = volume (MG)

$$\text{Chemical feed} = \frac{(d) \times (V) \times (8.34 \text{ lbs./gal})}{\text{Chemical purity}}$$

Where:
chemical fee = lbs.
d = dose (mg/L)
V = volume (MG)
Chemical purity = %, expressed as decimal

$$\text{Feed rate} = (d) \times (Q) \times (8.34 \text{ lbs./gal})$$

Where:
feed rate = lbs./day
d = dose (mg/L)
Q = flow (MGD)

$$\text{Feed rate} = \frac{(d) \times (Q) \times 8.34 \text{ lbs./gal}}{\text{Chemical Purity}}$$

Where:
feed rate = lbs./day
d = dose (mg/L)
Q = flow (MGD)
Chemical purity = %, expressed as decimal

$$\text{Feed rate} = \frac{(C) \times (V) \times (1{,}440 \text{ min/day})}{(T) \times (1{,}000 \text{ mg/g}) \times (453.6 \text{ g/lb.})}$$

Where:
feed rate = lbs./day
C = concentration (mg/mL)
V = volume pumped (mL)
T = time pumped (min.)

Chemical Feed Pump Formulas

$$\text{Chemical Feed Stroke} = (Q_d/Q_m) \times 100\%$$

Where:
chemical feed stroke, expressed as %
Q_d = desired flow
Q_m = maximum flow

$$\text{Feed pump rate} = \frac{(Q) \times (d) \times (3.785\ L/gal) \times (1{,}000{,}000\ gal/MG)}{(L) \times (24\ hr/day) \times (60\ min/hr)}$$

Where: feed pump rate =mL/min
Q = flow (MDG)
d = dose (mg/L)
L = liquid (mg/mL)

$$\text{Watts} = V \times A$$

Where: Watts = DC or AC circuit
V = volts
A = amps

PUMPS

Pumping Formulas

$$\text{Pumping Rate} = V/T$$

Where: pumping rate in gal/min
V = volume (gal.)
T = time (min.)

$$\text{Pumping Rate} = \frac{L \times W \times D \times 7.48\ gal/ft^3}{T}$$

Where: pumping rate in gal/min
L = length (ft.)
W = width (ft.)
D = depth (ft.)
T = time (min.)

$$\text{Pumping Rate} = \frac{0.785 \times d^2 \times D \times 7.48\ gal/ft^3}{T}$$

Where: pumping rate in gal/min
d = diameter (ft.)
D = depth (ft.)
T = time (min.)

$$\text{Time to Fill} = \frac{\text{Tank volume}}{\text{Flow Rate}}$$

Where: time to fill in min.
tank volume in gal.
flow rate in gal/min.

Horsepower, Motor & Pump Efficiency

$$whp = \frac{F \times H}{3{,}960}$$

Where: whp = water horsepower
F = flow (gpm)
H = head (ft.)

$$bhp = \frac{F \times H}{3{,}960 \times PE}$$

Where: bhp = brake horsepower
F = flow (gpm)
H = head (ft.)
PE = pump efficiency (%, as decimal)

$$bhp = whp/PE$$

Where:
bhp = brake horsepower
whp = water horsepower
PE = pump efficiency (%, as decimal)

$$mhp = \frac{F \times H}{3{,}960 \times PE \times ME}$$

Where
F = flow (gpm)
H = head (ft.)
PE = pump efficiency (%, as decimal)
ME = motor efficiency (%, as decimal)
mbp=motor horsepower

$$mhp = bhp/ME$$

Where:
mhp = motor horsepower
Bhp = brake horsepower
ME = motor efficiency (%, as decimal)

$$ME = (bhp/mhp) \times 100\%$$

Where:
ME = motor efficiency (%)
bhp = brake horsepower
mhp = motor horsepower

$$PE = (whp/bhp) \times 100\%$$

Where:
PE = pump efficiency (%)
whp = water horsepower
bhp = brake horsepower

$$\text{Efficiency} = \frac{\text{hp output}}{\text{hp supplied}} \times 100\%$$

Where:
efficiency is %

$$\text{Overall Efficiency} = (whp/mhp) \times 100\%$$

Where:
overall efficiency is %
whp = water horsepower
mhp = motor horsepower

$$\text{Wire to water efficiency} = \frac{whp}{\text{Power input or mhp}}$$

Where:
wire to water efficiency is %
whp = water horsepower
mhp = motor horsepower
power input is hp

$$\text{Wire to water efficiency} = (PE \times ME) \times 100\%$$

Where:
wire to water efficiency is %
PE = pump efficiency (%)
ME = motor efficiency (%)

Static Head = Suction lift + Discharge Head

Where:
Static Head in ft.
Suction Lift in ft.
Discharge Head in ft.

Static Head = Discharge Head – Suction Head

Where:
Static Head in ft.
Discharge Head in ft.
Suction Head in ft.

$$\text{kW usage} = (hp/ME) \times (.746\text{kW})$$

Where:
ME = motor efficiency (%)
hp = horsepower

Friction Loss = (0.1) x (Static Head)

Where: Friction Loss is ft.
Static Head is ft.

**** use this formula in absence of other data**

Total Dynamic Head = Static Head + Friction Loss

Where: Total Dynamic Head is ft.
Static Head is ft.
Friction Loss is ft.

Cost= (Motor hp)x(0.746 kW/hp)x(Cost$/kW-hr)

Where: Cost is $/hr.

POWER

1hp= .746kW; 1hp=746W; 1kW=1.34hp

Wastewater Treatment Ponds

PL = (Population)/(A)

Where: PL = population loading (persons/acre)
Population = population served(persons)
A = pond area (acres)

V = (A) x (d)

Where: V = pond volume (ac-ft.)
A = pond area (acres)
d = pond depth (ft.)

V (gal) = [V (ac-ft.)] x (43,560 ft^2/ac) x (7.48 gal/ft^3)

Where: V = pond volume

A = [(L) x (W)]/ (43,560 ft^2/ac)

Where: A = pond area (acre)
L = length (ft.)
W = length (ft.)

DT = (V)/(Q)

Where: DT = detention time (days)
V = volume (gal)
Q = flow (gal/day)

OLR = (BOD)/(A)

Where: OLR = organic loading rate (lbs./day/acre)
BOD = influent BOD (lbs./day)
A = pond areas (acres)

OLR = [(BOD) x (Q) x (8.34 lbs./gal)]/(A)

Where: OLR = organic loading rate (lbs./day/acre)
BOD = influent BOD (mg/L)
Q = flow (MGD)
A = pond areas (acres)

HLR = [(Q)/(A)] x 12 in/ft.

Where: HLR = hydraulic loading rate (in/day)
Q = flow (ac-ft/day)
A = pond area (acres)

Loading Formulas (general)

Loading = (Concentration) x (Q) x (8.34 lbs/gal)

Where: Loading is TSS or BOD = lbs./day
Concentration of TSS or BOD = mg/L
Q = flow

Hydraulic loading rate = $\frac{\text{Flow}}{\text{A}}$

Where: Hydraulic Loading = gpd/ft^2
Flow = gpd
A = area (ft^2)

Surface loading rate or Surface overflow rate = $\frac{\text{Flow}}{\text{A}}$

Where: Surface Loading/Surface Overflow rate in gpd/ft^2
Flow = gpd
A = area (ft^2)

Temperature Conversions

°C = (°F – 32) x (0.566)

°F = (°C x 1.8) + 32

Where: °C = degrees Celsius
°F = degrees Fahrenheit

Formulas

Average (arithmetic mean) = (sum of all terms)/ (number of terms)

Average (geometric mean) = $\sqrt[n]{(X_1)(X_2)(X_3)(X_4) \ldots (X_n)}$

The nth root of the product of n numbers

Efficiency, % = = [(In – Out)/(In)] x 100%

WET WELL

Cycle time (min) = $\frac{\text{SV}}{\text{PC} - \text{Inflow}}$.

Where: SV = storage volume (gal)
PC = pump capacity (gpm)
Inflow = wet well inflow (gpm)

COLLECTION SYSTEM

Slope, % = $\left[\frac{\text{Drop or rise}}{\text{Distance}}\right]$ x 100% OR Slope, % = $\left[\frac{\text{Rise}}{\text{Run}}\right]$ x 100%

Velocity = F/A

Where: Velocity is ft./sec
F = flow (ft^3/sec)
A = area (ft^2)

Velocity = $\frac{\text{Distance}}{\text{Time}}$

Where: Velocity is ft./sec
D = distance (ft.)
T = time (sec)

DETENTION TIME

$$DT = \frac{(V) \times (1{,}440 \text{ min/day}) \times (60 \text{ sec/min})}{Q}$$

Where: DT = detention time (sec)
V = volume (gal)
Q = flow rate(gal/day)

$$DT = \frac{(V) \times (24 \text{ hr./day})}{Q}$$

Where: DT = detention time (hr.)
V = volume of tank or basin (gal)
Q = flow rate (gal/day)

$$DT = \frac{(V) \times (1{,}440 \text{ min/day})}{Q}$$

Where: DT = detention time (min)
V = volume (gal)
Q = flow rate (gal/day)

DT = (V)/(Q)

Where: DT = detention time (days)
V = volume of tank or basin (gal)
Q = flow rate (gal/day)

DT = (V)/(Q)

Where: DT = detention time (days
Q = flow (ac-ft./day)
Volume (ac-ft.)

WELL FORMULAS

Well Yield = V/T

Where: Well Yield in gpm
V = volume in gallons
T = time in minutes

Drawdown = PWL – SWL

Where: Drawdown in feet
PWL = pumping water level in ft.
SWL = static water level in ft.

Specific Capacity = Well Yield/Drawdown

Where: Specific capacity = gpm/ft.
Well Yield in gpm
Drawdown in ft.

PRESSURE

1ft water=0.433 psi   1psi=2.31ft of water

ACTIVATED SLUDGE

$$SVI = \frac{(SSV) \times (1{,}000 \text{ mg/L})}{MLSS}$$

Where: SVI = sludge volume index (mL/g)
SSV = settled sludge volume (mL/L)
MLSS = mixed liquor suspended solids(mg/L)

WATER/WASTEWATER LEVELS 3 & 4

$$BOD_5 = \frac{(DO_I - DO_F) \times 300}{V_{sample}}$$

Where: BOD_5 = mg/L
DO_I = initial DO (mg/L)
DO_F = final DO (mg/L)
V_{sample} = sample volume (mL)
BOD bottle = 300 mL

$$BOD_5 = \frac{(D_1 - D_2) - (S) \times (V_S)}{P}$$

BOD5=lbs./day
D_1 = DO of sample after prep (mg/L)
D_2 = DO of sample after 5-day incubation at 20°C (mg/L)
S = oxygen uptake of seed (S = 0 if sample not seeded)
V_S = volume of seed in test bottle (mL)
P = decimal volumetric fraction of sample used. (1/P = dilution factor)

$$\text{F/M ratio} = \frac{(\text{BOD or COD})}{\text{MLVSS}}$$

Where: BOD = biological oxygen demand (lbs./day)
COD = chemical oxygen demand (m)
MLSS = mixed liquor suspended solids(lbs.)

$$\text{COD} = \frac{(\text{Amt. of FAS in Blank}) \times (\text{Molarity of FAS Titrant}) \times 8000}{\text{Amt. of Sample}}$$

COD loading = (COD) x (Q) x (8.34 lbs./gal)

Where: COD loading = lbs./day
COD = chemical oxygen demand (mg/L)
Q = flow (MGD

MLSS (lbs.) = (MLSS, mg/L) x (V) x (8.34 lbs./gal)

Where: MLSS = mixed liquor suspended solids
V = aerator volume (MG)

$$\text{MLVSS (desired)} = \frac{(\text{BOD or COD})}{\text{F/M Ratio (desired)}}$$

Where: MLVSS = mixed liquor volatile suspended solids (lbs.)
BOD = biological oxygen demand lbs./day
COD = chemical oxygen demand (lbs./day)

SOLIDS

$$SS = \frac{(A - B) \times (1{,}000{,}000)}{V_{sample}}$$

Where: SS = suspended solids (mg/ L)
A = final weight of pan, filter & residue(g)
B = weight of prepared filter & pan (g)
V_{sample} = sample volume (mL

Waste Activated Sludge (WAS)

$$WAS = \left[\frac{(MLSS) \times (V_{aerator}) \times (8.34 \text{ lbs./gal})}{MCRT} \right] - [(SE\ SS) \times (Q_{Plant}) \times (8.34 \text{ lbs./gal})]$$

Where: WAS = lbs./day
MLSS = mixed liquor suspended solids (mg/L)
$V_{aerator}$ = aerator volume (MG)
SE SS = secondary effluent SS (mg/L)
Q_{Plant} = plant flow (MGD)
MCRT = days

Mean Cell Residence Time

$$MCRT = \frac{TSSAeration + TSS_{Clarifier}}{TSS_{Wasted} + TSS_{Effluent}}$$

Where: MCRT = days
$TSS_{Aeration}$ = aeration tank TSS (lbs.)
$TSS_{Clarifier}$ = clarifier TSS (lbs.)
TSS_{Wasted} = TSS wasted (lbs./day)
$TSS_{Effluent}$ = effluent TSS (lbs./day

$$MCRT = \frac{(MLSS) \times [(V_{aerator}) + (V_{clarifier})] \times (8.34 \text{ lbs./gal})}{[(WAS\ SS) \times (Q_{WAS}) \times (8.34 \text{ lbs./gal})] + [(SE\ SS) \times (Q_{Plant}) \times (8.34 \text{ lbs./g}}$$

Where: MCRT = days
Q_{Plant} = plant flow (MGD)
$V_{aerator}$ = aerator volume (MG)
SE SS = secondary effluent SS (mg/L)
$V_{clarifire}$ = final clarifier volume (MG)
WAS SS = waste activated sludge SS) (mg/L)
Q_{WAS} = WAS flow (MGD)
MLSS = mixed liquor suspended solids (mg/L)

$$MCRT = \frac{(MLSS) \times (V) \times (8.34 \text{ lbs./gal})}{[(WAS\ SS) \times (Q_{WAS}) \times (8.34 \text{ lbs./gal})] + [(SE\ SS) \times (Q_{Plant}) \times (8.34 \text{ lbs./gal})]}$$

Where: MCRT = days
MLSS = mixed liquor suspended solids (mg/L)
SE SS = secondary effluent SS (mg/L
WAS SS = waste activated sludge SS (mg/L)
Q_{WAS} = WAS flow (MGD)
Q_{Plant} = plant flow (MGD
V= aerator volume (MG)

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CONCENTRATION/DILUTION/SOLUTIONS FORMULAS

(C1 X V1) = (C2 X V2)

Where: C=concentration
V=volume/flow

$(N_1 \times V_1) + (N_2 \times V_2) = (N_3 \times V_3$

Where: $V_1 + V_2 = V_3$
N = normality
V = volume or flow

FLUORIDATION

Feed Rate, lbs./day = (Dose, mg/L)(Flow,MGD)(8.34lbs/gal) / AFI (%) x Purity (%)

Where: AFI=Available Fluoride Ion

Saturator Feed Rate, grams/min= (Dose, mg/L) (Flow, gal/min)/ (18,000)

Calculated Dosage, mg/L = (Fluoride, lbs.) (AFI, %) (Purity, %)/ (Flow, MGD)

FILTRATION

Backwash water volume, gal= (Backwash Rate, gal/min/sq. ft) (Backwash Time, min) (Filter Area, sq. ft)

Filter Production Rate, gal/min= (Filtration Rate, gal/min/sq. ft) (Filter Area, sq. ft)

Filter Production Rate, gal/day= (Filtration Production Rate, gal/min.) (1,440 min./day)

CHLORINATION/HTH

HTH, lb. = Chlorine, lb. / Available Chlorine, %, expressed as decimal

HTH, lbs. = (Desired Available Chlorine, %, expressed as decimal) (Desired Volume, gal)(8.34lbs/gal) / HTH Available Chlorine, % expressed as decimal

Chlorine, lb.= (HTH, lb.) (Available Chlorine, %, expressed as decimal)

Chlorine, lb. = (Available Chlorine, %, expressed as decimal) (Bleach Volume, gal) (8.34lbs/gal)

Chlorine Dosage, mg/L = (HTH Feed Rate, lb./day) (HTH Available Chlorine, % expressed as decimal) / (Flow, MGD) (8.34 lbs./gal)

Chlorine Feed Rate, lbs./day = (Dosage, mg/L) (Flow, MGD) (8.34 lbs./gal) / Chemical Purity, %, expressed as decimal