WASTEWATER OPERATOR'S FORMULA SHEET 2022

CONVERSION FACTORS								
π	=	Pi ≈ 3.14	1%	=	10,000 mg/L	1 liter (L)	=	1,000 milliliters (ml) & [1.0 ml water = 1.0 gm]
1 cubic foot (ft^3)	=	7.48 gallons				1 pound	=	0.454 kilograms (kg)
1 gallon	=	8.34 pounds (lbs) of water				1 MGD	=	1,000,000 gallons/day (gpd)
1 acre	=	43,560 square feet (ft^2)					=	694.4 gallons/minute (gpm)
1 PSI	=	2.31 feet of water				GPD	=	(gpm)(1,440 minutes/day)
1 cubic foot/second (CFS) or (ft^3/sec)	=	7.48 gallons/second (gps)				A change of 1 ° C	=	1.8 ° F change
	=	450 gallons/minute (gpm)				° C	=	[(° F)-32][5/9]
	=	646,272 gallons/day (gpd)				° F	=	[(9/5)(° C)]+32
specific gravity	=	Ratio of a substances mass to water (water sp.gr. = 1.0 g/ml)				1 ton	=	2,000 pounds (lbs)

COMMONLY USED FORMULAS					
[pounds formula] Daily Loading, (lbs/day)	=	(Concentration, mg/L)(Flow, MGD)(8.34, lbs/gal)	Percent (%) Removal	=	$\left[\frac{(\text{in} - \text{out})}{\text{in}}\right][100]$
Population Equivalent, (PE)	=	$\frac{\text{Daily Loading, lbs}}{(\text{PE factor, daily lbs/person})}$	Detention Time, (hrs)	=	$\frac{(\text{Tank Volume, ft}^3)(7.48\ \text{gal./ft}^3)(24\ \text{hrs/day})}{\text{Flow (gallons/day)}}$
Daily Loading, (lbs/day)	=	(PE)(PE Factor, daily lbs/person)	Pipe Slope (grade)	=	$\frac{\text{rise or drop}}{\text{run}} = \frac{\text{difference in height}}{\text{difference in length}}$
Volume Rectangular Tank, (gallons)	=	(L, ft)(W, ft)(H, ft)(7.48, gal/ft^3)	Chlorine Dose, (mg/L)	=	(Chlorine Demand, mg/L) + (Chlorine Residual, mg/L)
Volume Circular Tank, (gallons)	=	(π)(R^2, ft)(H, ft)(7.48, gal/ft^3) or (0.785)(D^2, ft)(H, ft)(7.48, gal/ft^3)	Dosage, (mg/L)	=	$\frac{(\text{chemical feed, lbs/day})}{(\text{flow, MGD})(8.34\ \text{lbs/gal})}$
Return Sludge Rate, (MGD)	=	$\frac{(\text{Total Flow, MGD})(\text{Settleable Solids, \%})}{100\%}$	Decimal Fraction	=	$\frac{(\text{percent})}{100}$

CLARIFIER & SETTLING					
(SOR) Surface Settling (Overflow) Rate, (gal/day/ft^2)	=	$\frac{\text{Flow, gpd}}{\text{Surface Area, ft}^2}$	(WOR) Weir Overflow Rate, (gal/day/ft)	=	$\frac{\text{Flow, gpd}}{\text{Weir Length, ft}}$
Sludge Solids, (lbs)	=	(Sludge Volume, gal)(% Solids/100)(8.34 lbs/gal)			
Raw Sludge (RAS) Pumping, (gpm)	=	$\frac{(\text{Settleable Solids, ml/L})(\text{Plant Flow, gpm})}{1000\ \text{ml/L}}$			
Solids Loading, (lbs/ft^2)	=	$\frac{(\text{Plant Flow, MGD} + \text{RAS Flow, MGD})(\text{MLSS, mg/L})(8.34\ \text{lbs/gal})}{\text{Clarifier Surface Area, ft}^2}$			

SLUDGE					
Total Solids (%)	=	$\frac{[\text{weight of dry (oven) sludge}][100]}{\text{weight of wet sludge}}$	Digester Loading Rate, (lbs/day/ft^3)	=	$\frac{(\text{Volatile Solids added, lb/day})}{\text{Digester Volume, ft}^3}$
Volatile Solids (%)	=	$\frac{[\text{weight of material lost by burning}][100]}{\text{weight of dry (oven) sludge}}$	Composting Mixture Moisture (%)	=	$\frac{\left[\left[(\text{Sludge, lb})\left(\frac{\text{moisture\%}}{100\%}\right)\right] + \left[(\text{Compost, lb})\left(\frac{\text{moisture\%}}{100\%}\right)\right]\right][100\%]}{(\text{Sludge, lb}) + (\text{Compost, lb})}$

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ACTIVATED SLUDGE

(BOD) load on aeration tank, (lbs BOD/1,000 ft^3/day)	=	$\frac{\text{BOD, lbs/day}}{\text{(Volume of Aeration Tank, } ft^3\text{)}/1{,}000}$	(SVI) Sludge Volume Index, (ml/gm)	=	$\frac{\text{(Settleometer reading in 30 minutes, ml)}(1{,}000)}{\text{(MLSS, mg/L)}}$
(MLSS) Mixed Liquor Suspended Solids under aeration, (lbs)	=	(MLSS, mg/L)(8.34 lbs/gal)(Vol, MGD)	(MCRT) Mean Cell Residence Time, (days)	=	$\frac{\text{(Aeration MLSS, lbs)} + \text{(2° clarifier blanket MLSS, lbs)}}{\text{(MLSS wasted, lbs/day)} + \text{(SS loss in effluent, lbs/day)}}$
(SA) Sludge Age, (days)	=	$\frac{\text{Aeration Tank SS, lbs}}{\text{Aeration Tank influent SS, lbs/day}}$	(SA) Sludge Age, (days)	=	$\frac{\text{(MLSS, mg/L)(8.34 lbs/gal)(Vol. of tank, MG)}}{\text{(Influent SS, mg/L)(8.34 lbs/gal)(Flow, MGD)}}$
(F/M) Food to Microorganism Ratio	=	$\frac{\text{Aeration Tank influent BOD, lbs/day}}{\text{Aeration Tank MLVSS, lbs}}$	(F/M) Food to Microorganism Ratio	=	$\frac{\text{(BOD, mg/L)(8.34 lbs/gal)(Flow, MGD)}}{\text{(MLVSS, mg/L) (8.34 lbs/gal)(Vol. of tank, MG)}}$
(OUR) Oxygen Uptake Rate, (mg/L/hr)	=	$\frac{\text{(Initial DO, mg/L) – (Final DO, mg/L)}}{\text{(Duration of Measurement, min)(60 min/hr)}}$	(RR) Respiration Rate, (mg/hr/g)	=	$\frac{\text{(Oxygen uptake rate, mg/L/hr)}(1{,}000\ \text{mg/g})}{\text{(MLSS, mg/L)}}$

WASTEWATER LAGOONS or STABILIZATION PONDS

Lagoon or Pond Side Slope	=	$\frac{\text{Run}}{\text{Rise}}$; example 3:1 = $\frac{\text{3 ft. Horizontal}}{\text{1 ft. Vertical}}$	Daily Rise (inches)	=	$\frac{\text{(Flow, gal/day)(Design Operating Depth, inches)}}{\text{Volume of Pond, gal}}$
Daily Volume of Pond Discharge, (gallons/day)	=	(Drop in Pond, ft/day)(Average Surface Area, acres)(325,851 gal/acre-ft)			
Volume of a Pond, (gallon)	=	(Average surface area, ft^2)(design operating depth, ft)(7.48 gal/ft^3)			
Average Surface Area, (ft^2)	=	$\frac{\text{(Top Area, } ft^2\text{)} + \text{(}\mathbf{\text{Bottom Area}}\text{, } ft^2\text{)}}{2}$	**Bottom Area**, ft^2	=	(Bottom Length, ft)(Bottom Width, ft)
			Bottom Length, ft	=	(Top Length, ft)-[(2)(side slope)(depth, ft)]
			Bottom Width, ft	=	(Top Width, ft)-[(2)(side slope)(depth, ft)]
Organic Loading into Aerated Lagoon (lbs/1,000 ft^3/day)	=	$\frac{\text{Influent BOD, lbs/day}}{\text{Lagoon Volume, } ft^3\text{/1,000}}$	Organic Loading on Stabilization Pond, (lbs/acre/day)	=	$\frac{\text{Influent BOD, lbs/day}}{\text{Total surface area of pond(s), acres}}$

LAND APPLICATION

Required Land, (acres)	=	$\frac{\text{Total Weight of Sludge, tons/year}}{\text{Limit, tons/acre}}$	Sludge Application, (dry lbs)	=	(Sludge, Gal.)(8.34 lbs/gal)(% Solids in Sludge/100)

FLOW

Flow Rate	=	$\frac{\text{Volume}}{\text{Time}}$; example $\frac{\text{cubic feet}}{\text{second}}, \frac{\text{gallons}}{\text{minute}}$	Flow (pumping) Rate	=	$\frac{\text{(Volume Pumped)}}{\text{(Time)}}$
Velocity	=	$\frac{\text{Distance}}{\text{Time}}$; example $\frac{\text{miles}}{\text{hours}}, \frac{\text{feet}}{\text{minutes}}, \frac{\text{feet}}{\text{seconds}}$	Q (flow)	=	(Velocity)(Cross Sectional Area)
Volume, (gpm)	=	(ft^3/second)(60 seconds/minute)(7.48 gal/ft^3)	Volume pumped, (gpm)	=	$\frac{(\pi)(R^2,\ \text{in}^2)(H, \text{in})(\text{RPM})}{231\ \text{in}^3\text{/gal}}$
	=	$\frac{\text{(volume displaced by piston, in}^3\text{/stroke) (RPM)}}{231\ \text{in}^3\text{ /gal}}$			

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PUMPS

Q = Flow, gpm H = Total Dynamic Head, ft. E_p = Pump Efficiency, *as a decimal* E_m = Motor Efficiency, *as a decimal*

Water HP	=	$\frac{(Q)(H)}{(3{,}960)}$				
Brake HP	=	$\frac{(Q)(H)}{(3{,}960)(E_p)}$	=	$\frac{Water\ HP}{E_p}$		
Motor HP	=	$\frac{(Q)(H)}{(3{,}960)(E_p)(E_m)}$	=	$\frac{Water\ HP}{(E_p)(E_m)}$	=	$\frac{Brake\ HP}{E_m}$
Cost, ($/day)	=	(Motor HP)(0.746 kW/HP)(Operating Time, hrs)($/kWh)				
Flow, (gpm)	=	(0.785)(Bore, ft^2)(Stroke, ft)(7.48 gal/ft^3)(strokes/minute)				
Flow, (gallons)	=	(0.785)(Bore, ft^2)(Stroke, ft)(7.48 gal/ft^3)(strokes/minute)(Pumping Time, minutes)				
Chemical Feed Pumps, (gpd)	=	$\frac{\left(\frac{\text{ml}}{\text{min}}\right)(1{,}440\ \text{min/day})}{(1{,}000\ \text{ml/L})(3.785\ \text{L/gal})}$				
Chemical Feed Rate, (ml/min)	=	$\frac{\left(\frac{\text{gal}}{\text{day}}\right)(1{,}000\ \text{ml/L})(3.785\ \text{L/gal})}{(1{,}440\ \text{min/day})}$				
Percent (%) of Chemical in Solution from Dry Stock	=	$\frac{Part}{Whole}$	=	$\left[\frac{\text{Dry Chemicals, lbs}}{[(\text{Volume water, gal})(8.34\ \text{lbs/gal})] + [\text{Dry Chemicals/lbs}]}\right][100]$		*Chemical, g + Water, g = Solution, g*
Mixture Strength (%)	=	(Vol.1)(Conc.1) = (Vol.2)(Conc.2) & (Vol.1)(Conc.1) + (Vol.2)(Conc.2)= (Vol.3)(Conc.3)				

LABORATORY RESULTS

mg/L	=	$\frac{(g)(1{,}000\text{mg/g})(1{,}000\text{ml/L})}{(\text{sample, ml})}$	=	ppm	% Solids	=	$\frac{(\text{MLSS, mg/L})}{(10{,}000\ \text{mg/L}/1\%)}$	
(BOD) unseeded, (mg/L)	=	$[(\text{Initial DO, mg/L}) - (\text{Final DO, mg/L})]\left(\frac{\text{Bottle Vol, ml}}{\text{Sample Vol, ml}}\right)$			Seed Correction Formula	=	$\left(\frac{(\text{Initial DO, mg/L}) - (\text{Final DO, mg/L})}{\text{Seed used, ml}}\right)$	
(BOD) seeded, (mg/L)	=	$\{[(\text{Initial DO, mg/L}) - (\text{Final DO, mg/L})] - [(\text{Seed, ml})(\text{Seed correction, mg/L/ml})]\}\left(\frac{\text{Bottle Vol, ml}}{\text{Sample Vol, ml}}\right)$						
(TS) Total Solids, (mg/L)	=	$\frac{(\text{Dish Residue, mg})(1{,}000\ \text{ml/L})}{(\text{Sample, ml})}$			(VS) Volatile Solids, (mg/L)	=	$\left(\frac{[(\text{before burning, g}) - (\text{after, g})][1000\ \text{mg/g}]}{(\text{Sample, ml})(\text{L}/1000\ \text{ml})}\right)$	
(TSS) Total Suspended Solids, (mg/L)	=	$\frac{(\text{Dry Filtered Solids, mg})}{(\text{Sample, ml})(1\ \text{L}/1{,}000\ \text{ml})}$			(% VS) Volatile Solids	=	$\left(\frac{\text{VS, g}}{\text{TS, g}}\right)(100)$	
(TSS) Total Suspended Solids, (mg/L)	=	$\frac{[(\text{Dried Solids \& Filter Paper, g}) - (\text{F. Paper, g})][1{,}000\ \text{mg}/1\ \text{g}]}{(\text{Sample, ml})(\text{L}/1000\ \text{ml})}$			(VSS) Volatile Suspended Solids, (mg/L)	=	$\frac{(\text{VSS, g})(1{,}000{,}000)}{(\text{Sample Vol., ml})}$	
(F/M) Food to Microorganism Ratio	=	$\frac{(\text{BOD, mg/L})(8.34\ \text{lbs/gal})(\text{Flow, MGD})}{(\text{MLVSS, mg/L})\ (8.34\ \text{lbs/gal})(\text{Vol. of tank, MG})}$			Geometric Mean	=	$Antilog\left[\frac{(\text{Sum of } \log_{10} \text{ of all samples})}{(\text{Number of Samples})}\right]$	

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ANAEROBIC DIGESTERS

Volatile Solids Loading, (lbs VS/day/ ft^3)	=	$\frac{\text{Feed Sludge VS, lbs/day}}{\text{Digester Volume, } ft^3}$	Detention Time, (days)	=	$\frac{\text{Digester Volume, gal}}{\text{Sludge Feed, gpd}}$
Volatile Solids Reduced, (%)	=	$\left[\frac{(\text{VS in} - \text{VS out})}{(\text{VS in}) - [(\text{VS in})(\text{VS out})]}\right][100]$	VS Loading, (lbs/ft^3)	=	$\frac{\text{VSS influent, lbs}}{\text{Digester Volume, } ft^3}$

ROTATING BIOLOGICAL CONTACTORS

Hydraulic Loading Rate, (GPM/ft^2)	=	$\frac{\text{GPM}}{\text{Media Surface Area, } ft^2}$	Hydraulic Loading Rate, (GPD/ft^2)	=	$\frac{\text{Total Flow including recirculation, GPD}}{\text{Media Surface Area, } ft^2}$
Organic BOD Loading Rate, (lbs/1,000 ft^3/day)	=	$\frac{\text{Soluble BOD applied, lbs/day}}{\text{Media Surface Area, } ft^2/1{,}000}$	Soluble BOD applied, (lbs/day)	=	(Soluble BOD, mg/L)(Flow, MGD)(8.34, lbs/gal)
Soluble BOD, (mg/L)	=	(Total BOD, mg/L) – (Suspended BOD, mg/L)			

OXIDATION DITCHES

(F/M) Food to Microorganism Ratio	=	$\frac{\text{BOD, lbs/day}}{\text{MLVSS, lbs}}$	=	$\frac{(\text{BOD, mg/L})(8.34\ \text{lbs/gal})(\text{Flow, MGD})}{(\text{MLVSS, mg/L})\ (8.34\ \text{lbs/gal})(\text{Ditch Vol., MG})}$		
BOD Loading Rate, (lbs/1,000 ft^3/day)	=	$\frac{\text{BOD, lbs/day}}{(\text{Ditch Vol., } ft^3)/1000}$	Ditch Detention Time, (hours)	=	$\frac{(\text{Ditch Volume, MG})(24\ \text{hours/day})}{\text{Flow, MGD}}$	
(SA) Sludge Age, (days)	=	$\frac{\text{Solids under Aeration, lbs}}{\text{Solids added, lbs/day}}$	Aeration Solids, (lbs)	=	(MLSS, mg/L)(Ditch Volume, MG)(8.34, lbs/gal)	
			Solids added, (lbs/day)	=	(Inf SS, mg/L)(Flow, MGD)(8.34, lbs/gal)	
Ditch Volume, ft^3	=	(Total Length, ft)(Area, ft^2)	(Total Length, ft)	=	[(2)(π)(radius, ft)]+[(2)(straight length, ft)]	
			(Area, ft^2)	=	$\left[\frac{(\text{width bottom,ft})+(\text{width top,ft})}{2}\right]$[depth, ft]	

TERTIARY FILTRATION

Filter Flow, (gpm)	=	(Filter Area, ft^2)(Filter Rate, gpm/ft^2)
Filter Backwash Volume, (gal)	=	(Filter Area, ft^2)(Backwash Flow, gpm)(Time, min.)
Filter Backwash Flow, (gpm)	=	(Filter Area, ft^2)(rise or fall, ft/min.)(7.48 gal/ft^3)
Filter Backwash Rate, (gpm/ft^2)	=	$\frac{(\text{Backwash Flow Rate, gpm})}{(\text{Filter Area, } ft^2)}$

WATERWAYS DISCHARGE

Diluted Concentration, (mg/L)	=	$\frac{[(\text{Stream Conc.}_1\text{, mg/L})(\text{Stream Flow}_1\text{, MGD})] + [(\text{Stream Conc.}_2\text{, mg/L})(\text{Stream Flow}_2\text{, MGD})]}{(\text{Stream Flow}_1\text{, MGD}) + (\text{Stream Flow}_2\text{, MGD})}$

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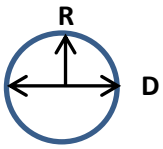
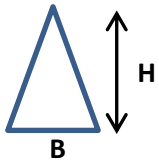
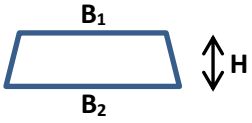
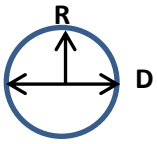
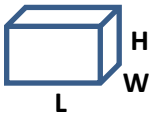
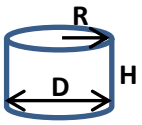
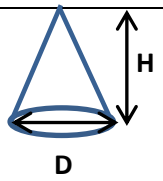
CALCULATIONS OF PERIMETERS*		
Rectangles or Squares (P)	=	S1 + S2 + S3 + S4 
Circles *Circumference* (C)	=	πD π(2R) 
Other Plane Figures (P)	=	Sum of all sides

**EXAMPLE UNITS*

Perimeter:	*yd, ft, in*
Area:	*yd^2, ft^2, in^2*
Volume:	*yd^3, ft^3, in^3*

CALCULATIONS OF AREAS*		
Square or Rectangle (A)	=	(L)(W) 
Triangle (A)	=	$\frac{(B)(H)}{2}$ 
Trapezoid (A)	=	$\left[\frac{(B_1)+(B_2)}{2}\right][H]$ 
Circle (A)	=	$(\pi)(R^2)$ or $(0.785)(D^2)$ or $\frac{(\pi)(D^2)}{4}$ 

CALCULATIONS OF VOLUMES*		
Rectangular solids (V)	=	(L)(W)(H) 
Cylinder (V)	= = =	$(\pi)(R^2)(H)$ or $(0.785)(D^2)(H)$ or $\frac{(\pi)(D^2)(H)}{4}$ 
Cones (V)	= =	$\frac{(\pi)(R^2)(H)}{3}$ or $\frac{(0.785)(D^2)(H)}{3}$ 
Pyramids (V)	=	$\frac{(A)(H)}{3}$, (*A* = area of base)