Sidney's Big Book of Water and Wastewater Math

INDIGO WATER GROUP

Unit Conversions to Know by Heart

1 inch = 2.54 centimeters
1 meter = 3.28 feet
1 mile = 5280 feet

1 acre = 43,560 ft^2
1 m^2 = 10.76 ft^2

1 gallon = 3.785 liters
1 ft^3 = 7.48 gallons
1 m^3 = 35.31 ft^3

1 ft water = 0.433 psi

1 gallon = 8.34 lbs when specific gravity is 1.0
1 kg = 2.2 lbs

1% = 10,000 mg/L
1 mg/L = 1 ppm
1 μg/L = 1 ppb

1 day = 1440 minutes
1 hp = 0.746 kW

1 gram = 15.43 grains
1 grain per gallon = 17.1 mg/L

Water Formulas

pounds per day = (concentration in mg/L)*(flow rate in mgd)*(8.34)

chlorine dose = demand + residual

velocity = $\frac{\text{flow}}{\text{area}}$ $\qquad V = \frac{Q}{A}$

flow rate = $\frac{\text{volume}}{\text{time}}$ $\qquad Q = \frac{V}{t}$

overflow rate = $\frac{\text{flow rate}}{\text{area}}$

weir loading rate = $\frac{\text{flow rate}}{\text{feet of weir}}$

(concentration 1)*(volume 1) = (concentration 2)*(volume 2) $\qquad C_1V_1 = C_2V_2$

(conc. 1)*(volume 1) + (conc. 2)*(volume 2) = (conc. 3)*(volume 3)

$$C_1V_1 + C_2V_2 = C_3V_3$$

horsepower = $\frac{\text{(flow in gpm)*(lift in feet)}}{3960}$

Solids Handling and Digestion

PERCENT VSS REDUCTION

DIGESTION IS A RESIDUAL SOLIDS TREATMENT PROCESS THAT IS BASED ON THE PRINCIPAL THAT, WHEN THERE IS AN INADEQUATE SUPPLY OF FOOD (BOD) AVAILABLE, MICROORGANISMS WILL METABOLIZE OR EAT THEIR OWN CELLULAR MASS.

DIGESTION OF SOLIDS:

1) MAKES SLUDGE RELATIVELY INERT.
2) REDUCES ODORS.
3) REDUCES BACTERIA AND PATHOGENIC ORGANISMS.
4) REDUCES THE VOLUME AND WEIGHT OF SLUDGE.

BIOSOLIDS 503 REGULATION REQUIRES A 38% REDUCTION IN THE PERCENTAGE OF VOLATILE SUSPENDED SOLIDS.

CALCULATE AS:

$$\%VSS\ REDUCTION = \frac{(\%VSS_{IN} - \%VSS_{OUT})}{(\%VSS_{IN} - (\%VSS_{IN} * \%VSS_{OUT}))} * 100$$

EXAMPLE:

WAS Conc = 8000 mg/L TSS
6400 mg/L TVSS

Digested solids = 12,000 mg/L TSS
8,040 mg/L TVSS

WHAT IS THE % VSS REDUCTION?

$$\% \ VSS = \left[\frac{TVSS}{TSS}\right] * 100$$

$$\% VSS_{WAS} = \frac{6400 \ mg/L}{8000 \ mg/L} * 100$$

$$= 80\%$$

$$\% VSS_{OUT} = \frac{8,040 \ mg/L}{12000 \ mg/L} * 100$$

$$= 67\%$$

$$\% VSS \ REDUCTION = \frac{(\% VSS_{IN} - \% VSS_{OUT})}{(\% VSS_{IN} - (\% VSS_{IN} * \% VSS_{OUT})} * 100$$

$$\% VSS \ REDUCTION = \frac{(0.80 - 0.67)}{(0.80 - (0.80 * 0.67))} * 100$$

$$= 49.2\%$$

SOLIDS HANDLING

1. Feed solids to an anaerobic digester contain 80% volatile solids (VS) and the digested solids contain 50% VS. Compute the VS reduction.
   a) 23.1%
   b) 37.5%
   c) 40.0%
   d) 75.0%

?Operations Forum September 1997

2. How many lbs/day of suspended solids are removed by a primary clarifier given the following: Flow rate = 2.7 MGD, Influent TSS = 230 mg/l, Primary effluent TSS = 110 mg/l
   a) 3204 lbs/day
   b) 2702 lbs/day
   c) 2683 lbs/day

3. Determine the organic loading to an anaerobic digester given the following: Digester volume = 50,000 cubic feet, Feed sludge volume = 8000 lbs/day, %TS = 4.5%, %VS = 74%
   a) 0.05 lbs VS/cubic ft/day
   b) 0.11 lbs VS/cubic ft/day
   c) 0.08 lbs VS/cubic ft/day

4. If a sludge draw off of 8000 gallons contains 6% solids, how many lbs. were pumped?
   a) 2842 lbs.
   b) 2916 lbs.
   c) 4003 lbs.
   d) 16091 lbs.

5. Given the following, what is the digester detention time? Diameter = 80 ft Depth = 25 ft Sludge feed rate = 25000 gpd
   a) 37.6 days
   b) 47.8 days
   c) 25.2 days

6. The volume of a primary anaerobic digester is 40,000 cubic feet. The raw sludge feed rate is 6000 lbs dry sludge per day and the volatile solids content is 78%. What is the organic loading rate in lbs VS/cubic foot/day?
   a) 8.5
   b) 0.117
   c) 0.305
   d) 6.2

7. Given the following information, calculate the %VSS reduction in the digester.
Influent %VSS = 80%   Effluent %VSS = 67%

a) 49%
b) 67%
c) 13%
d) 81%

8. Primary sludge containing 5% solids is pumped to a digester continuously at a rate of 25 gal/min. How many pounds of volatile solids are added to the digester each day if total solids are 73% volatile solids?

a) 1310 lb/d
b) 1800 lb/d
c) 9830 lb/d
d) 10,960 lb/d
e) 15,010 lb/d

?Operations Forum February 1999

9. If a gravity sludge thickener receives 20 gpm of primary sludge at a concentration of 3.0% total solids, and the thickener overflow solids concentration is 0.15% total solids, what is the solids removal efficiency?

a) 92
b) 93
c) 95
d) 97

?Operations Forum February 1997

10. How many pounds of solids are pumped to a digester each day if the digester receives a 10,000 gal/d load containing 5% total solids?

a) 1,668,000 lb/d
b) 5250 lb/d
c) 4170 lb/d
d) 864,000 lb/d

?Operations Forum November 1998

11. A jar test conducted on 1 liter of secondary sludge with 1.5% total solids requires 50 ml of a 0.10% solution of dry polymer for flocculation. Determine the polymer dosage in lb/ton of solids.

a) 5.5
b) 6.7
c) 7.6

?Operations Forum May 1998

12. What is the solids recovery rate of a belt filter press with the following operational data? Hours of operation = 10; solids filtered = 80,000 gal; solids content = 5%; cake solids = 22%; cake produced = 68 wet tons.
a) 20%
b) 63%
c) 82%
d) 90%
?Operations Forum May 1998

13. If solids have a cadmium concentration of 20 mg/kg dry weight, and the allowable biosolids land-spreading limit is 10 lb/ac of cadmium, what is the maximum application rate of biosolids in tons per acre?
a) 114 ton/ac
b) 187 ton/ac
c) 223 ton/ac
d) 250 ton/ac
?Operations Forum April 1997

14. Primary sludge is produced at a rate of 40,000 pounds per day. If the sludge contains 6% solids, how many gallons of sludge will need to be pumped out of the primary clarifiers?
a) 79936 gallons per day
b) 7993605 gallons per day
c) 89126 gallons per day
d) 60012 gallons per day

15. Primary sludge is produced at a rate of 25,000 gallons per day and contains 6% solids. After dewatering, the primary sludge contains 17% solids. How many gallons of sludge remain after dewatering?
a) 8823 gallons per day
b) 7500 gallons per day
c) 70833 gallons per day
d) 10510 gallons per day

16. Calculate the solids loading rate in ppd/sft for a gravity thickener given the following information: The thickener is 50 feet in diameter and 15 feet deep. Feed sludge contains 5% solids and enters at a flow rate of 130 gpm.
a) 39.8 ppd/sft
b) 35.7 ppd/sft
c) 9.94 ppd/sft
d) 45.3 ppd/sft

JOB SOLIDS HANDLING JOB NO. 108

SHEET NO. ____ OF ____

CALCULATED BY ____ DATE ____

CHECKED BY ____ DATE ____

SUBJECT ____

1. FIRST, CONVERT PERCENTAGES TO DECIMAL FORM

80% → 0.8

50% → 0.5

$$\%\text{ VS Reduction} = \frac{(In - Out)}{In - (In * Out)}$$

$$\%\text{ VS Reduction} = \frac{(0.8 - 0.5)}{0.8 - (0.8)(0.5)}$$

$$= \frac{0.3}{0.8 - 0.4}$$

$$= \frac{0.3}{0.4}$$

$$= 0.75 \quad \text{OR} \quad 75\%$$

2. $ppd = (mg/L)(Q, mgd)(8.34)$

$ppd = (230 - 110\ mg/L)(2.7\ mgd)(8.34)$

$ppd = (120\ mg/L)(2.7\ mgd)(8.34)$

$ppd = 2702$

3. total lbs of loading = 8000 ppd

74% of the total is volatile sollids, so

$$(8000\ ppd)(0.74) = 5902\ ppd\ VS$$

$$\frac{lbs\ VS}{cuft} = \frac{5902\ ppd\ VS}{50{,}000\ cuft}$$

$$= 0.1184\ \frac{pound\ VS}{day \cdot cuft}$$

JOB SOLIDS HANDLING JOB NO. 109
SHEET NO. OF
CALCULATED BY DATE
CHECKED BY DATE
SUBJECT

4. $1\% = 10{,}000\ mg/L$

$6\% \left| \frac{10{,}000\ mg/L}{1\%} \right| = 60{,}000\ mg/L$

$8000\ gallons \left| \frac{1\ MG}{1{,}000{,}000\ gal} \right| = 0.008\ mgd$

$ppd = (mg/L)(Q, mgd)(8.34)$
$ppd = (60{,}000\ mg/L)(0.008\ mgd)(8.34)$
$ppd = 4003$

5. $FLOW = \frac{VOLUME}{TIME}$

$Volume = \pi r^2 h$
$V = (3.14)(40\ ft)(40\ ft)(25\ ft)$
$V = 125600\ ft^3$

$125600\ ft^3 \left| \frac{7.48\ gal}{1\ ft^3} \right| = 939{,}488\ gallons$

$25{,}000\ \frac{gal}{day} = \frac{939{,}488\ gallons}{t}$
$(25{,}000)(t) = 939{,}488$
$t = 37.6\ days$

6. $(6000\ lbs\ dry\ sludge)(0.78\ Volatile) = 4680\ lbs\ VS$

$\frac{lb\ VS}{cu ft\ day} = \frac{4680\ lbs\ VS}{40{,}000\ cu ft}$

$= 0.117$

JOB Solids Handling JOB NO. 110

SHEET NO. ____ OF ____

CALCULATED BY ____ DATE ____

CHECKED BY ____ DATE ____

SUBJECT ____

7. % VS Reduction $= \frac{(In - Out)}{In - (In)(Out)}$

$= \frac{(0.8 - 0.67)}{0.8 - (0.8)(0.67)}$

$= \frac{0.13}{0.8 - 0.536}$

$= \frac{0.13}{0.264}$

$= 0.49 \longrightarrow 49\%$

8. $5\% \left| \frac{10{,}000 \text{ mg/L}}{1\%} \right| = 50{,}000 \text{ mg/L}$

$\frac{25 \text{ gal}}{\text{min}} \left| \frac{1440 \text{ min}}{1 \text{ day}} \right| \frac{1 \text{ mg}}{1{,}000{,}000 \text{ gal}} \bigg| = 0.036 \text{ mgd}$

ppd = (mg/L)(Q, mgd)(8.34)

ppd = (50,000 mg/L)(0.036 mgd)(8.34)

ppd = 15,012 ← TOTAL SOLIDS

(15,012 ppd total solids)(0.73) = 10959 ppd Volatile Solids

9. Removal Efficiency $= \left[\frac{In - Out}{In}\right] * 100$

$= \left[\frac{3.0 - 0.15}{3.0}\right] * 100$

$= 95.0\%$

JOB SOLIDS HANDLING JOB NO. 111

SHEET NO. ______ OF ______

CALCULATED BY ______ DATE ______

CHECKED BY ______ DATE ______

SUBJECT ______

10. 1% = 10,000 mg/L

$$\frac{10{,}000 \text{ gal}}{\text{day}} \bigg| \frac{1 \text{ mg}}{1{,}000{,}000 \text{ gal}} \bigg| = 0.01 \frac{\text{mg}}{\text{day}}$$

ppd = (mg/L)(Q, mgd)(8.34)
ppd = (50,000 mg/L)(0.01 mgd)(8.34)
ppd = 4170

11. $0.10\% \text{ polymer} \bigg| \frac{10{,}000 \text{ mg/L}}{1\%} \bigg| = 1{,}000$ mg/L polymer conc.

USED $50 \text{ mL} \bigg| \frac{1 \text{ L}}{1000 \text{ mL}} \bigg| \frac{1000 \text{ mg}}{1 \text{ L}} \bigg| = 50$ mg added to 1L JAR TEST

$$\frac{1.5\% \text{ TS}}{\text{LITER}} \bigg| \frac{10{,}000 \text{ mg}}{1\%} \bigg| = 15{,}000 \text{ mg TS/LITER}$$

IT'S A COMPLICATED UNIT CONVERSION

$$\frac{50 \text{ mg Polymer}}{15{,}000 \text{ mg TS}} \bigg| \frac{1 \text{ g}}{1000 \text{ mg P}} \bigg| \frac{1 \text{ kg}}{1000 \text{ g P}} \bigg| \frac{1 \text{ lb Poly}}{2.2 \text{ lbs P}} \bigg| \frac{1000 \text{ mg TS}}{1 \text{ g}} \bigg| \frac{1000 \text{ g TS}}{1 \text{ kg}} \bigg| \frac{2.2 \text{ kg TS}}{1 \text{ lb}} \bigg| = \frac{\text{lbs Poly}}{\text{lb TS}}$$

$$\frac{50 \text{ lbs Poly}}{15{,}000 \text{ lbs TS}} \bigg| \frac{2000 \text{ lbs TS}}{1 \text{ ton TS}} \bigg| = 6.7 \frac{\text{lbs Poly}}{\text{ton TS}}$$

JOB Solids Handling JOB NO. 112
SHEET NO. ______ OF ______
CALCULATED BY ______ DATE ______
CHECKED BY ______ DATE ______
SUBJECT ______

12. If 100% of the solids are captured, then the volumes will be directly porportional. Use the dilution eqn.

$C_1 V_1 = C_2 V_2$ * perfect conditions

$(5\%)(80{,}000 \text{ gal}) = (22\%)(V_2)$

$18182 \text{ gal} = V_2$

If one gallon weighs 8.34 lbs ... (approximately)

$18182 \text{ gal} \left| \frac{8.34 \text{ lbs}}{1 \text{ gal}} \right| \frac{1 \text{ ton}}{2000 \text{ lbs}} \Big| = 75.82 \text{ tons fed}$

$\% \text{ EFF} = \left[\frac{(\text{In} - \text{Out})}{\text{In}} \right] * 100$

$= \left[\frac{(75.82 - 68)}{75.82} \right] * 100$

$= 10.3\%$ not captured

∴ 89.6% captured

13. Just another unit conversion

$\frac{20 \text{ mg Cd}}{\text{kg Bio}} \Big| \frac{1 \text{ g Cd}}{1000 \text{ mg Cd}} \Big| \frac{1 \text{ kg Cd}}{1000 \text{ g Cd}} \Big| \frac{1 \text{ lb Cd}}{2.2 \text{ kg Cd}} \Big| \frac{2.2 \text{ kg Bio}}{1 \text{ lb Bio}} \Big| \frac{2000 \text{ lbs Bio}}{1 \text{ ton}} \Big| = 0.088 \frac{\text{lbs Cd}}{\text{ton Bio}}$

$\frac{10 \text{ lbs Cd}}{\text{acre}} \Big| \frac{1 \text{ ton Biosolids}}{0.088 \text{ lbs Cd}} \Big| = 113.6 \frac{\text{tons biosolids}}{\text{acre}}$

JOB SOLIDS HANDLING JOB NO. 113
SHEET NO. OF
CALCULATED BY DATE
CHECKED BY DATE
SUBJECT

14. 1% = 10,000 mg/L

ppd = (mg/L)(Q, mgd)(8.34)

40,000 ppd = (60,000 mg/L)(Q, mgd)(8.34)
0.0799 mgd = Q

$0.0799 \frac{mg}{day} \left| \frac{1,000,000 gal}{1 mg} \right| = 79,936$ gallons/day

15. USE THE DILUTION EQN.

$C_1 V_1 = C_2 V_2$
$(6\%)(25,000 \text{ gpd}) = (17\%)(V_2)$
$8823 \text{ gpd} = V_2$

16. $\frac{130 gal}{min} \left| \frac{1440 min}{1 day} \right| \frac{1 mg}{1,000,000 gal} \right| = 0.1872$ mgd

$5\% \left| \frac{10,000 mg/L}{1\%} \right| = 50,000$ mg/L

ppd = (mg/L)(Q, mgd)(8.34)
ppd = (50,000 mg/L)(0.1872 mgd)(8.34)
ppd = 78062.4

Area = πr^2
Area = (3.14)(25 ft)(25 ft)
Area = 1962.5 ft²

load rate = $\frac{\text{ppd solids}}{\text{area}}$
load rate = $\frac{78062.4 \text{ ppd}}{1962.5 \text{ ft}^2}$
load rate = 39.8 lbs/ft²·day